# CRINOIDS, A BLASTOID AND A CYCLOCYSTOID FROM THE UPPER DEVONIAN REEF COMPLEX OF THE CANNING BASIN, WESTERN AUSTRALIA

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This first systematic treatment of echinoderms from the extensive Upper Devonian reef complex of the northern Canning Basin erects the Frasnian blastoid *Hyperoblastus buglensis* sp. nov. and crinoids *Codiacrinus nicolli* sp. nov., *Melocrinites solidus* sp. nov. and *Hexacrinites brownlawi* sp. nov. and the Famennian crinoids *Jaekelicrinus murrayi* sp. nov., *Playfordicrinus kellyensis* gen. et sp. nov., *Wacrinus caseyensis* gen. et sp. nov. and *W. millardensis* gen. et sp. nov., with *J. murrayi* first appearing at the very top of the Frasnian. These echinoderms which have affinities with Siberian and European faunas occur mainly in the fine, red, fore reef Virgin Hills Formation with numerous holdfasts (some directly onto algal mounds) suggesting they lived in this environment. While much disaggregated crinoidal material is found in the cleaner reefal limestones the only cup found is *Stylocrinus tabulatus* Goldfuss, 1839 in Frasnian fore reef talus slope Sadler Limestone in the Paddy's Valley area. In the same insoluble residue was a marginal cyclocystoid plate, the youngest record of the class. ❐ *Crinoids, blastoid, cyclocystoid, Upper Devonian, Canning Basin.*

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Crinoidal remains have been recognised in the Upper Devonian reef complexes of the Canning Basin by many workers since the earliest days of exploration. However, only Teichert (1949) applied any generic level taxonomy to Devonian crinoids from the basin. He listed *Storthingocrinus*? nov. sp. from the Frasnian *Manticoceras* Zone, the fauna of which he collected in the Bugle Gap and No. 10 Bore areas; we have not been able to recollect that crinoid genus in those areas and a search of the collections of the University of Western Australia failed to produce Teichert's specimen. However, it seems possible that Teichert's material could be the same as that attributed below to *Stylocrinus tabulatus* Goldfuss, 1839 from Frasnian Sadler Limestone just to the W of Bugle Gap in Paddy's Valley. Blastoids and cyclocystoids have not previously been described from the Basin.

This is the first paper to describe Devonian echinoderms from the Canning Basin and includes the first knowledge of Upper Devonian crinoids, blastoids or cyclocystoids from the Southern Hemisphere. It represents the results of fewer than 10 collecting trips encompassing a small percentage of the Basin's Devonian outcrop. Judging from the volume of disaggregated crinoidal material encountered at most localities and the area of Devonian outcrop yet to be investigated in detail for echinoderms it seems highly probable that a much larger Upper Devonian fauna than the <10 taxa reported here will ultimately be discovered.

## GEOLOGICAL SETTING

All the fossils described herein come from the late Frasnian to Famennian part of the Devonian reef complexes along the northern margin of the Canning Basin. A great deal has been written about the geology of these reefs but the major geological mapping of the area was provided by Playford & Lowry (1966). Taxonomic studies with consequent biostratigraphic inferences have addressed most fossil groups found therein, including corals (Hill & Jell, 1970), brachiopods (Veevers, 1959), sponges (Rigby, 1986), stromatoporoids (Cockbain, 1984), crustacea (Briggs & Rolfe, 1983) and fish (Long, 1991) among others. However, the most useful groups for biostratigraphy have been conodonts (Glenister & Klapper, 1966; Druce, 1976) and goniatites (Glenister, 1958; Becker et al., 1993; Becker & House, 1997) and it is through these 2 groups that we have attempted to place the crinoids in stratigraphic sequence (Table 1).

All except 2 taxa come from the Virgin Hills Formation, which is a red muddy carbonate deposited on the fore reef slope and in inter-reefal

| | Conodont Zones | *Stylocrinus tabulatus* | *Hyperoblastus buglensis* | *Hexacrinites brownlawi* | *Taxocrinus* sp. | *Codiacrinus necolli* | *Playfordicrinus kellyensis* | *Jaekelicrinus murrayi* | *Melocrinites solidus* | *Forbesiocrinus* | *Wacrinus caseyensis* | *Wacrinus millardensis* | Catillocrinid | Localities |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Famennian | *trachyptera* | | | | | | | X | | | | | | NMVPL1950-56 |
| | *marginifera* | | | | | | | | | | X | X | | NMVPL1931 NMVPL1930 |
| | | | | | | | | X | | X | | | | NMVPL1930, NMVPL1939 |
| | *rhomboidea* | | | | | | X | X | | | | X | X | NMVPL1936, 1938, 1942 |
| | *crepida* | | | | | | | | | | | | | |
| | *P. triangularis* | | | | | | | X | | X | | | | NMVPL1929 |
| Frasnian | *linguiformis* | ? | X | X | X | X | | X | X | | | | | QML1029, QML1031 |
| | *gigas* | ? | | | | | | | | | | | | |
| | *A. triangularis* | ? | | | | | | | | | | | | |
| | *asymmetrica* | ? | | | | | | | | | | | | |

TABLE 1. Stratigraphic distribution of crinoids described, against international conodont biozonation taken from Talent et al., 1993; localities detailed in Appendix are listed against this conodont scale.

shallow basins. The formation includes a variety of lithofacies indicating numerous environmental changes and events. It is not the aim of this paper to go into the geological history of the area which can be gleaned from the numerous references mentioned above. Crinoid holdfasts occur in situ on a number of bedding surfaces, especially ones representing stillstands or transgressive periods when sedimentation rates were extremely slow. Crinoidal debris, including cups, is scattered throughout most horizons but is most abundant with the holfasts. The cup of only one species, *Stylocrinus tabulatus* Goldfuss, 1839, and a wide variety of stem debris are known from the Sadler Limestone which is a reef talus deposit representing a higher energy environment. Doubtless, crinoids were common on the reefs but were disarticulated after death. No doubt more will be found in the reef limestones especially where silicified faunas are etched free but at this stage our knowledge of them remains poor. The single marginal ossicle of a cyclocystoid found in the same insoluble residue as *S. tabulatus* cannot be generically assigned but its occurrence extends the range of the class which was previously unknown in strata younger than Eifelian (Europe).

## SYSTEMATICS

Material described herein is housed in the Museum of Victoria (NMVP), Queensland Museum (QMF), Australian Geological Survey Organisation (CPC) and Geological Survey of Western Australia (GSWA) and comes from localities (Appendix 1) catalogued in the Museum of Victoria (NMVPL) and Queensland Museum (QML). All the specimens are preserved as carbonate, probably original skeleton, in a muddy carbonate matrix. They are variously weathered and are photographed in this state after blackening with a monomolecular layer of colloidal graphite and whitening with ammonium chloride sublimate. Terminology follows Moore & Teichert (1978). Measurements are given as: length, parallel to the central axis; width, transverse to, but never cutting or joining the central axis; and depth, normal to, and may join the central axis.

Phylum ECHINODERMATA
Class BLASTOIDEA Say, 1825
Order SPIRACULATA Jaekel, 1918
Family HYPEROBLASTIDAE Fay, 1964

We follow the family concept of Waters & Horowitz (1993).

### **Hyperoblastus** Fay, 1961

TYPE SPECIES. (by original designation) *Pentremitidea preciosa* Reimann, 1945 (=*Pentremitidea filosa* Whiteaves, 1887) from the Middle Devonian of Ontario.

DIAGNOSIS. See Breimer & Dop, 1975.

### **Hyperoblastus buglensis** sp. nov. (Figs 1-4)

ETYMOLOGY. From Bugle Gap.

MATERIAL. HOLOTYPE: QMF36161. PARATYPES: QMF36162-36168, 40357-40359. All from QML1031, on E side of Bugle Gap S of Wagon Pass.

DIAGNOSIS. Conical pelvis, low vault, pelvic angle c.70°, with 3 hydrospires per group; lancet concealed, with raised diamond-shaped adoral end, with sharp dorsal ridge.

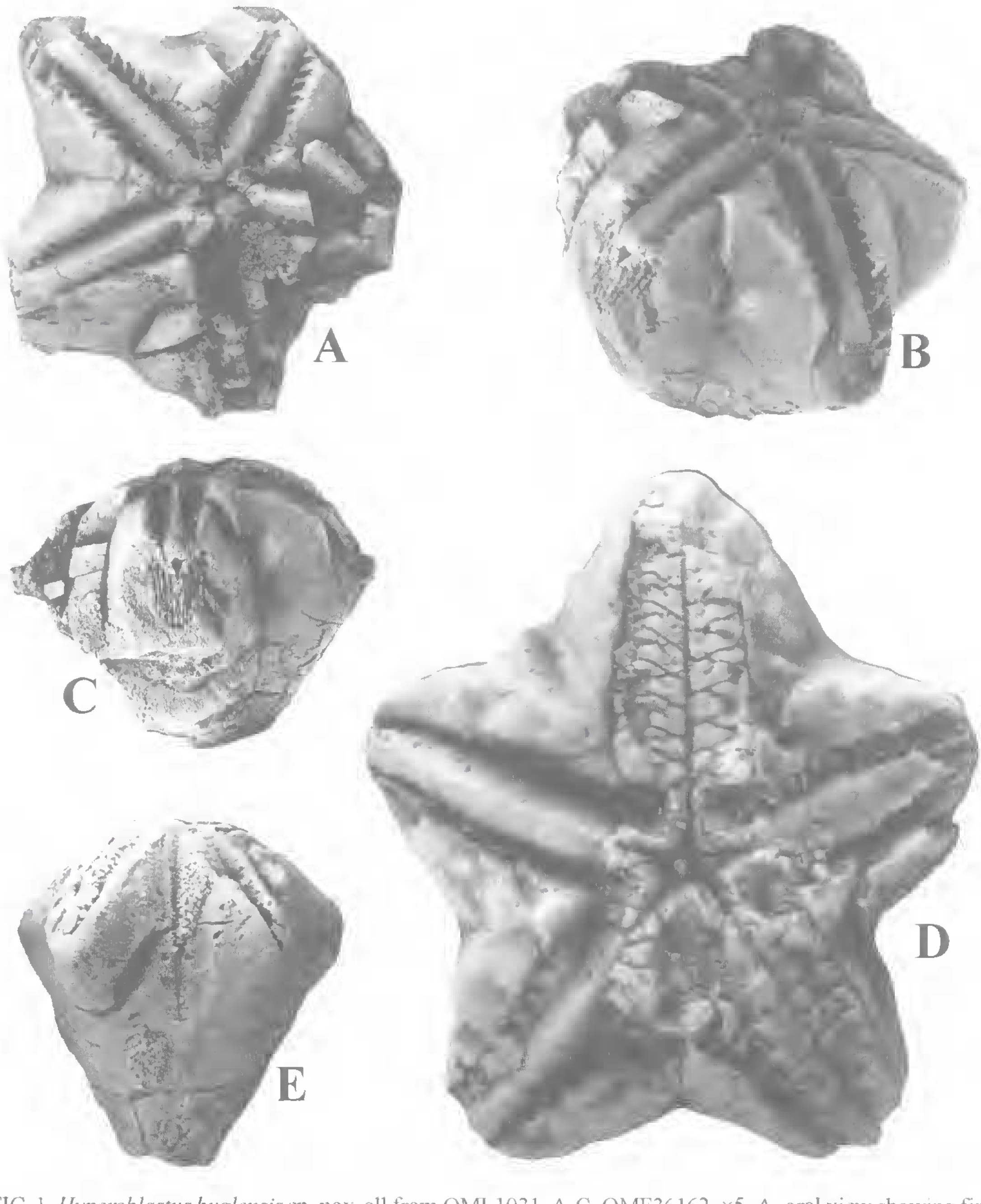



FIG. 1. *Hyperoblastus buglensis* sp. nov. all from QML1031. A-C, QMF36162, ×5. A, oral view showing fine pores from hydrospires. B, oblique oral view. C, lateral view of B ambulacrum showing hydrospire slits. D,E, oral and lateral views of QMF36161, ×12 and ×5, respectively.

DESCRIPTION. Cup smooth, up to 12mm long and 12mm wide at tips of ambulacra, conical, made up of conical pelvis with straight sides, capped by convex vault (Figs 1E, 3H); vault: pelvis = 1:2; pelvic angle 65-72° (av. 68°; N=7) Cross section at greatest width pentastellate. Basals 3, normally arranged, with 2 large hexagonal and one smaller pentagonal azygous. Radials 5, up to 8mm high, with convex radial fronts in lateral view; RD axis less than RB axis

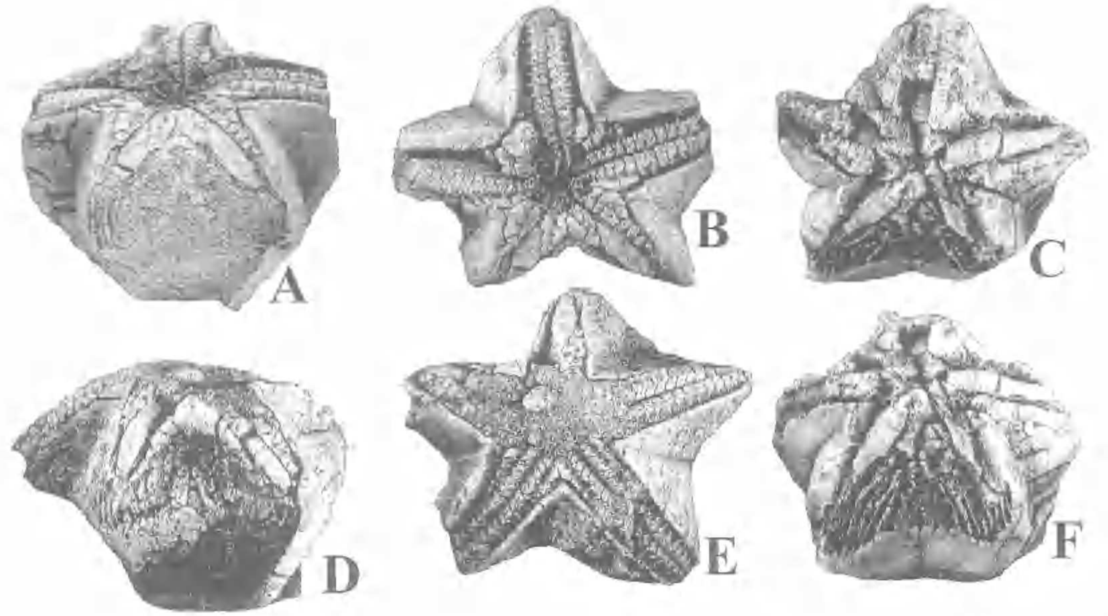



FIG 2. *Hyperoblastus buglensis* sp. nov. all from QML1031. A,B, QMF40357, ×6. A, oblique posterior view. B, oral view. C,F, QMF40358, ×6. C, oral view. F, oblique posterior view. D,E, QMF40359, ×4. D, oblique posterior view. E, oral view.

at all sizes; RD front straight. Deltoids concealed by radials and ambulacral side plates except for narrow adoral lip, separated from radials by suture highly oblique to radial surface (Fig. 1A,D); adoral lips of deltoids contiguous as peristome. Spiracles 4 plus slightly larger anispiracle, each descending into deltoid at very low angle to external surface dividing into 2 at depth within deltoid but deltoid septum only evident in weathered specimens, connecting into the hydrospire canals on either side of the lancet. Anal deltoids 3, a superdeltoid, a subdeltoid and a hypodeltoid (Fig. 4C); superdeltoid slightly wider than other deltoid lips, sutured aborally and laterally to raised anterior diamond of lancet. Lancet concealed except adoral end; prominent raised diamond-shaped adoral end sutured to aboral lateral ends of each deltoid lip, forming lateral margins to spiracles, crossed by radial median groove, abutting most adoral side plates; rest of lancet with obtuse but sharp upper keel, with row of uniform shallow concavities along each upper surface accommodating the inner side plates and alternating with similar concavities in the radial adjoining each ambulacrum accommodating the outer side plates. Side plates in 2 alternating columns on each side of each ambulacrum, up to 15 per column; inner side plates larger and reaching to outer margin of ambulacrum except in adoral 1/3 but triangular outer side plates never reaching midline of ambulacrum. Side plates filling grooves between lancet and radials; access to hydrospires via a series of pores at outer margin of ambulacrum. Hydrospire groups 10, extending some distance into coelomic cavity from sides of ambulacra, 3 hydrospires per group, no hydrospire plate. Stem, brachioles and cover plates unknown.

REMARKS. This Western Australian species is assigned to *Hyperoblastus* on its thecal shape, concealed lancet, radials covering main body of the deltoids, 5 spiracles and deltoid septum at depth within spiracles but not at surface. The phylogeny of the family has been discussed by Breimer & Dop (1975), Horowitz et al. (1986) and Waters & Horowitz (1993) and the occurrence and morphology of the new species do not conflict with their conclusions. The family is known from Europe, North America and China and its occurrence in the Frasnian of WA is in accord with European affinities of other elements of the fauna (Teichert, 1949). Breimer & Macurda (1972: 290) remarked on the paucity of blastoids in the Frasnian and Famennian worldwide; they acknowledged only a few specimens of *Hyperoblastus* from the Frasnian of the United States so the occurrence in the latest Frasnian of Western Australia suggests the

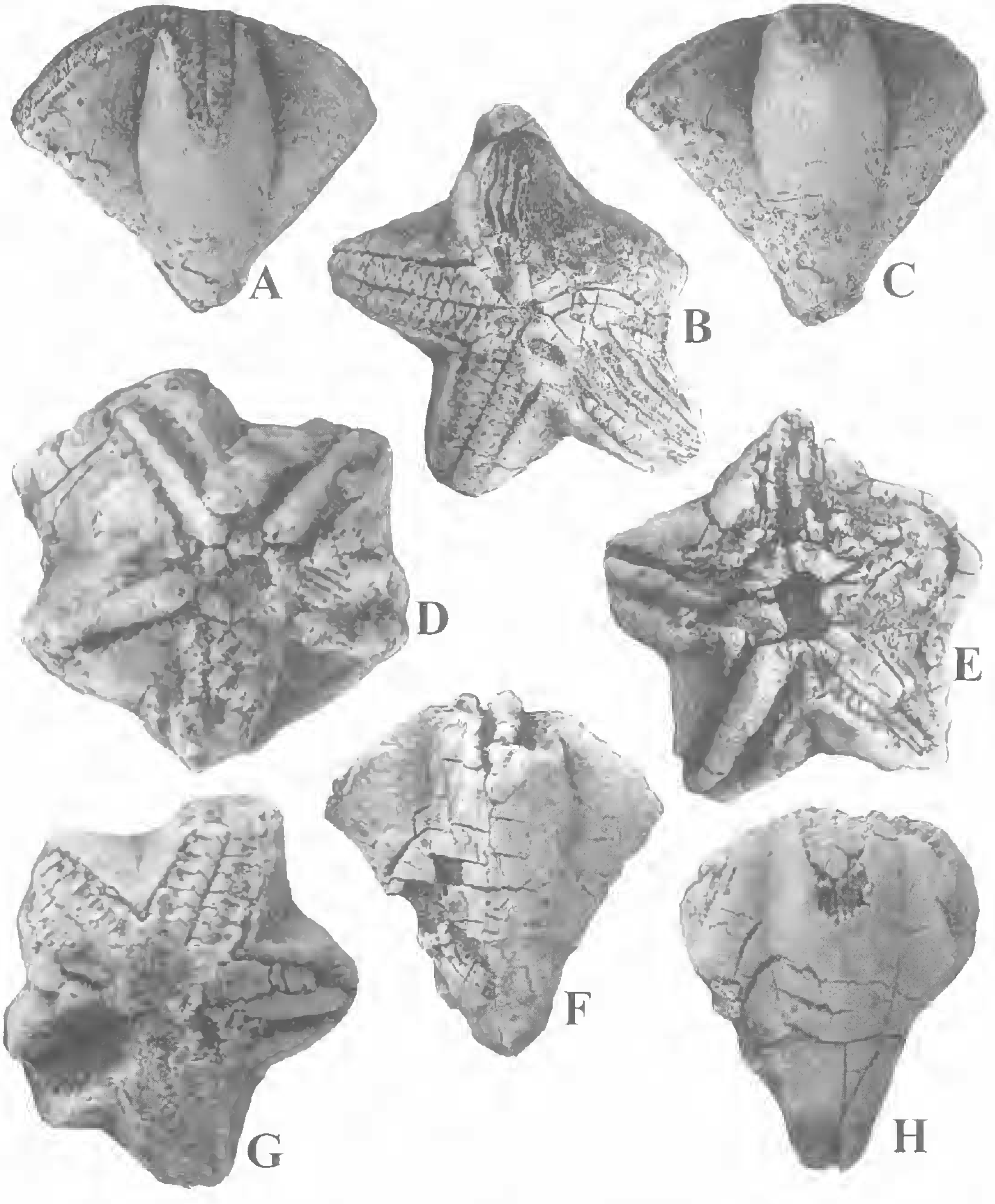


FIG. 3. *Hyperoblastus buglensis* sp. nov. all from QML1031. A-C, QMF36163. A, C, lateral oblique and lateral views, ×4. B, oral view, ×5. D, oral view of QMF36164, ×7. E,F, oral and lateral views of QMF36165, ×9 and ×5, respectively. G, H, oral and lateral views of QMF36166, ×7 and ×6, respectively.

lineage continued, but evidence of any other blastoid lineages is still lacking for this interval. Lane et al. (1997) erected *Sinopetaloblastus* from the Famennian of NW China and assigned it to the Hyperoblastidae but it is quite different, in gross shape, ambulacral structure and anal plating, from the new Australian form. Waters (1988) remarked that most blastoid genera were

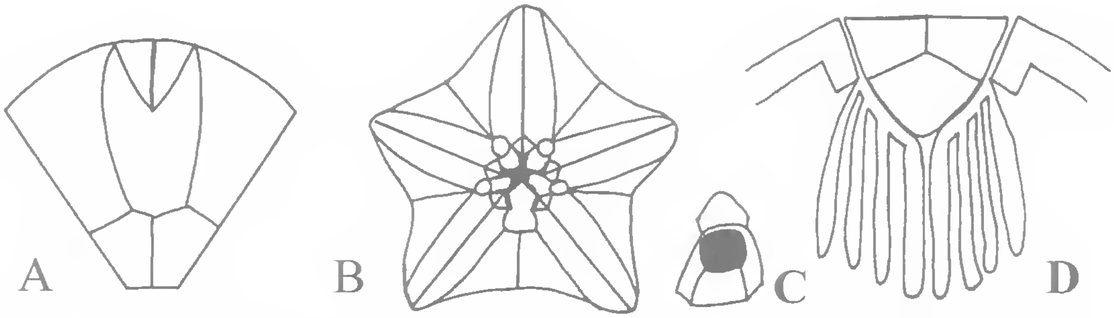



FIG. 4. *Hyperoblastus buglensis* sp. nov. A, lateral outline showing convex vault and straight sides. B, distal view showing spiracles, raised diamond-shaped adoral ends of lancets, and ambulacral tracts. C, analdeltoid arrangement with super-, sub- and hypodeltoid (composite from Fig. 2B showing hypodeltoid, Fig. 1D showing superdeltoid and Fig. 2F showing subdeltoid; each specimen at different level of weathering to expose different elements). D, cross section of an ambulacral tract to show arrangement of deltoids, lancet and hydrospires.

restricted to one or a few localities and very short time ranges; although *Hyperoblastus* has wide geographic and stratigraphic ranges the new species is known from only one locality and horizon.

Among known *Hyperoblastus*, only *H. eifelensis* (Roemer,1852) and *H. lusitanicus* (Etheridge & Carpenter, 1882) have the conical pelvis and low vault characteristic of the new species. The former is distinguished by the much greater number of hydrospire folds in each ambulacrum (Fay, 1961, text-fig. 84) and the latter is distinguished by its much smaller pelvic angle, smaller outer side plates and different sectional shape of the lancet (Fay, 1961, text-figs 90-93).

Subclass CAMERATA
Order MONOBATHRIDA
Suborder COMPSOCRININA
Superfamily HEXACRINITOIDEA Wachsmuth & Springer, 1885
Family HEXACRINITIDAE
Wachsmuth & Springer, 1885

**Hexacrinites** Austin & Austin, 1843

TYPE SPECIES. *Platycrinus interscapularis* Phillips, 1841 from the Devonian of England; by original designation.

**Hexacrinites brownlawi** sp. nov.
(Figs 5,6)

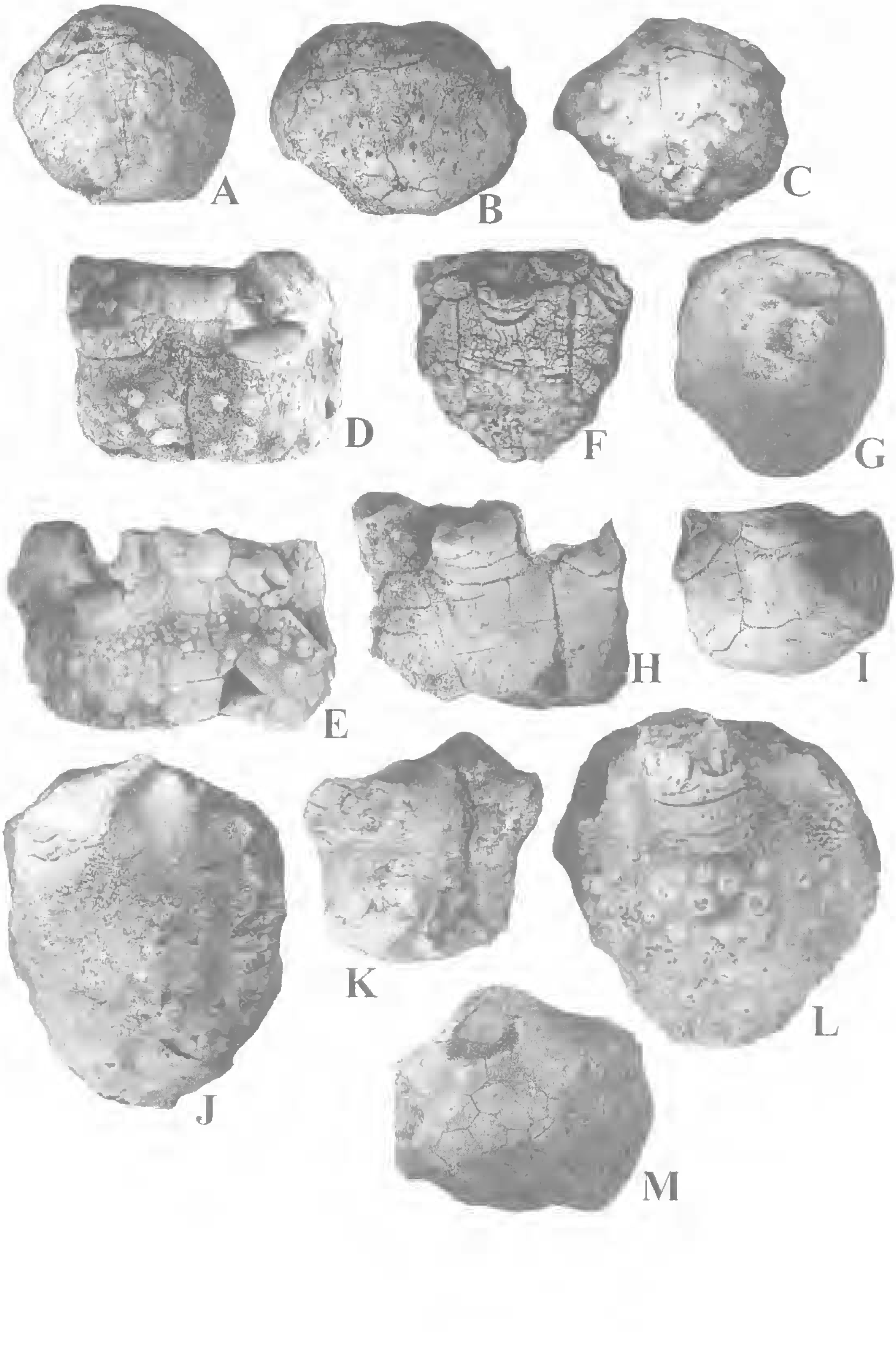
ETYMOLOGY. For Scott Brownlaw who collected some of the material.

MATERIAL. HOLOTYPE: GSWA115324. PARATYPES: QMF36169-36179, 40356. All from QML1031, on E side of Bugle Gap S of Wagon Pass.

DIAGNOSIS. Ornament of a few coarse tubercles with concave tips on most of theca, with distinct change to finely granulose ornament distally from just proximal to radial facet. Second primibrach axillary.

DESCRIPTION. Cup subcylindrical with widely flaring conical base, up to 28mm long and 22mm in diameter. Basal circlet hexagonal, of 3 equal plates; stem attachment facet moderately large, up to 6mm in diameter, with fine narrow marginal crenularium. Basals to radials suture usually wavy. Radials large, with convex proximal margin, with short upper lateral projections beside wide peneplenary radial facets. First primibrach tapering laterally, narrower distally, with crenellate articulation facets proximally and distally. Second primibrach axillary, subtriangular and of variable width in lateral view, also with crenellate articulating facets. First secundibrachs of uniform length, thick, with wide deep ambulacral groove just beginning to divide. Rest of arms unknown. Primanal of similar size to radial,

FIG. 5. *Hexacrinites brownlawi* sp. nov. all from QML1031. A-C, oblique basal views of QMF36169, ×4, QMF36170, ×2, and QMF36171, ×2, respectively. D,E, 2 interadial lateral views of QMF36172, ×3. F, lateral view of weathered theca QMF36173, ×2. G, basal view of QMF36174, ×3. H, I, lateral views of incomplete thecae QMF36175 and QMF36176, ×2. J-L, QMF36177, ×2. J, C-D interradial view showing anal tube on right. K, oral view with anal tube at 6 o'clock. L, lateral view showing low axillary 2nd primibrach. M, distal view of theca QMF36178, ×2.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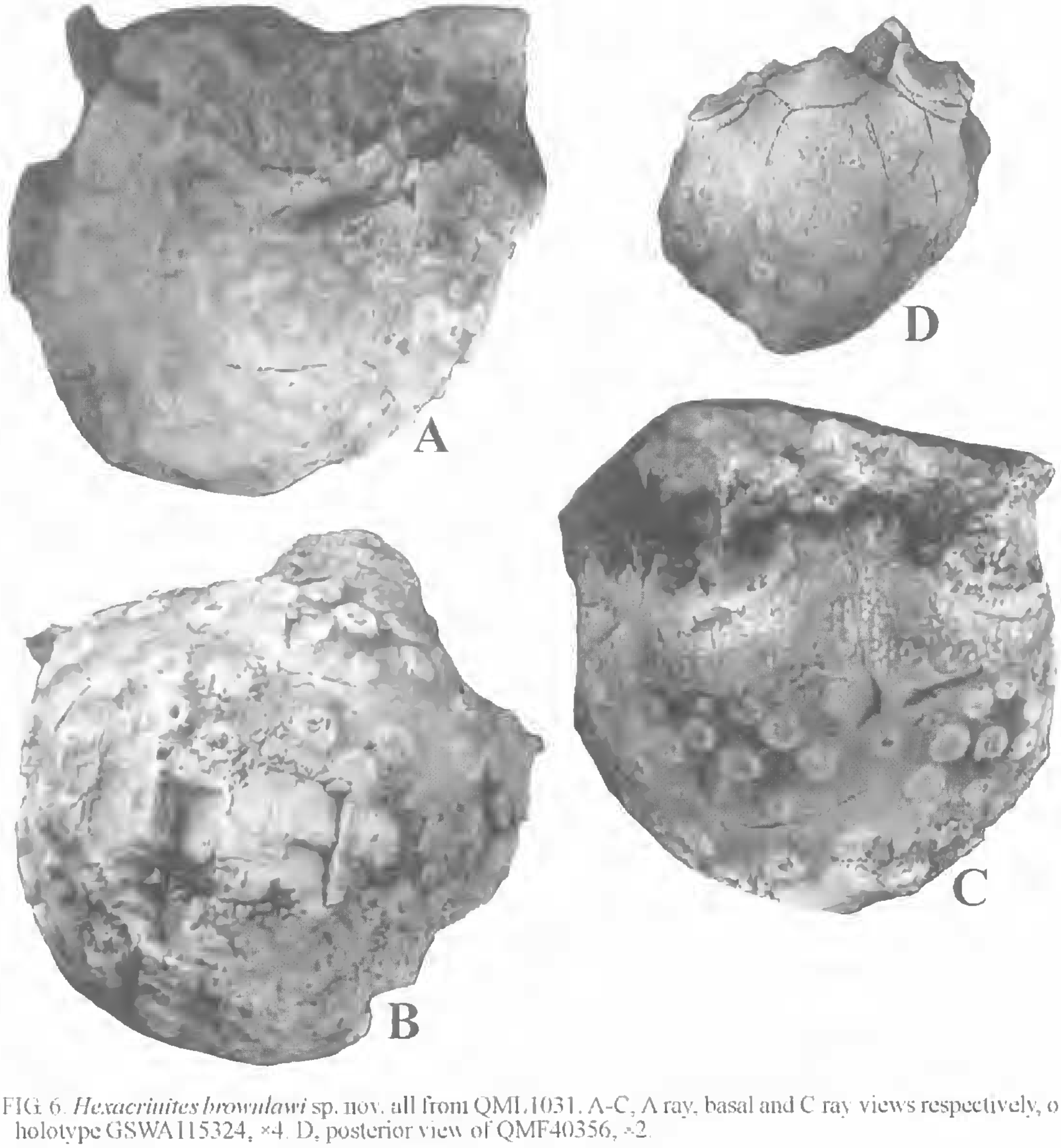



FIG. 6. *Hexacrinites brownlawi* sp. nov. all from QML1031. A-C, A ray, basal and C ray views respectively, of holotype GSWA115324, ×4. D, posterior view of QMF40356, ×2.

supporting 1 large tegminal plate distally. Anal opening on small spire rising from theca distal to 1st row of tegminal plates distal to primanal. Interprimibrachs 1 per interradius, large, supporting 1 or 2 smaller tegminal plates. Tegmen convex, inflated well distal to arm bases, longest anteriorly, sloping to posterior; tegminal plates of uniform size, polygonal, with central peak. Ornament on basals and radials proximal to arm bases, of few irregularly distributed large tubercles; tubercles with concave tips, usually more concentrated just proximal to radial facet, in one specimen (Fig. 5G) forming circlet around stem facet on slightly longer thecal base; distal to arm bases ornament changes sharply, becoming finely granulose.

REMARKS. Thecal shape resembles a number of other species of the genus including *H. spinosus* Muller, 1856 which occurs in the Middle Devonian of Queensland (Jell et al., 1988) but the inflated tegmen and ornament are distinctive.

## **Wacrinus** gen. nov.

TYPE SPECIES. *Wacrinus caseyensis* sp. nov.

ETYMOLOGY. For Western Australia.

DIAGNOSIS. First primibrach axillary. Fixed arms not forming protruberant brachial lobes but first free arm plates directed outward. Anal opening through tegmen in C ambulacral series of small plates; no anal tube developed. Tegmen plating usually strongly differentiated, with a single large interambulacral in each interray except CD where a number of smaller plates are present, with many ambulacral plates of varying sizes, with 5 orals at intersection of ambulacral tracts.

REMARKS. *Wacrinus* could be related to *Arthroacantha* Williams, 1883 from the Devonian of Europe and North America by its slender stem, ornament, single large interprimibrach and subtle ray ridges but that genus has 2 primibrachs per ray. *Cerasmocrinus* Strimple & Levorson, 1973 (type *Hexacrinus springeri* Thomas, 1924) from the Upper Devonian of Iowa was excluded from the Hexacrinitidae (and placed in the Desmidocrinidae) because its interprimibrachs penetrate the interradial area of the theca. However, its interprimibrachs bear exactly the same relationship to the tegmen, arms and radials as do those of *Hexacrinites interscapularis* (Ubaghs, 1978, fig. 279.1b,c) and *Wacrinus*; the only differences are in the extent to which the arms are fixed in the cup and relative size of radials and primibrachs. We suggest *Cerasmocrinus* should be returned to the Hexacrinitidae and is allied to *Wacrinus*.

Gary Lane (pers. comm. 1998) has drawn our attention to *Adelocrinus* Phillips, 1841 from the Famennian of SW England which he is currently revising and which he considers a valid genus related to *Arthroacantha* but separated from it by having only 1 primibrach (like *Wacrinus*). In so far as both *Adelocrinus* and *Arthroacantha* have articulating spines on the cup and this feature (presence or absence of spines) is not observable on the tuberculate *W. millardensis* its assignment to one of those genera is not possible. However, the current review of *Adelocrinus* and/or better material of *W. millardensis* would provide better understanding of the relationships of the genera. The 2 new species described below could be separated generically by allying *W. millardensis* with the tuberculate *Adelocrinus* as opposed to the smooth *W. caseyensis*. We take note of the variety of ornament on different species of *Hexacrinites* from tuberculate to ridged to smooth in assigning the 2 species to the new genus.

## **Wacrinus caseyensis** sp. nov.
(Figs 7-11)

ETYMOLOGY. For Casey Falls adjacent to the collecting site; Casey Falls are named for John Casey who was involved in mapping the area during the 1950's.

MATERIAL. HOLOTYPE: NMVP100280. PARATYPES: NMVP100272-100279, 100281-100300, QMF36180, GSWA19390-19393, WAM91.719, 91.722, 91.723 all from NMVPL1931, above Casey Falls; further specimens, mostly less well-preserved from the type locality are held in the Museum of Victoria, Queensland Museum, Geological Survey of Western Australia and the Western Australian Museum.

DIAGNOSIS. As for genus.

DESCRIPTION. Cup subspherical, 10-30+ mm long; plates smooth, without median ray ridges, thick. Basals 3, equal, pentagonal, forming hexagonal circlet, with intervening sutures in B and E rays and in CD interray, with low indistinct circular ridge centrally surrounding depressed (first columnal fills depression) crenulate stem facet. Radials largest plates of cup, heptagonal, A, B and E radials symmetrical, but C and D radials slightly asymmetrical in that suture with 1st interprimibrach is noticeably longer than that with anal plate distal to primanal. First primibrach axillary, with 5 straight sides (angles between them suggest hexagonal shape), distal margin with 2 broad shallow scallops for secundibrachs; 1st secundibrachs fixed in cup; 2nd secundibrach unknown but probably free; intersecundibrachs absent; facet on axillary primibrach with sharp but low median ridge, with minutely crenulate outer margin, with pustulose to minutely ridged surface adorally in transversely symmetrical pattern, with distal part smooth except for 2 tiny axial canal openings. First interprimibrach large, hexagonal, with lateral margins converging distally, at level of axillary primibrach, supporting 2 hexagonal interprimibrachs in second level; 2nd row interprimibrachs with sutural margins to axillary primibrach and to 1st ambulacral plates of tegmen, supporting a single large interambulacral in most cases but in a few rare cases (Fig. 9I) supporting 2 interambulacrals and in 2 cases (Figs 7G, 9B) large interambulacral of AB and BC interray resting directly on 1st interprimibrach and separating 2 second row interprimibrachs. CD interray with large hexagonal primanal in radial series but not as large as radials; 2 hexagonal plates in 2nd row resting on primanal and with distally converging lateral margins; 3rd row usually with 3 smaller plates

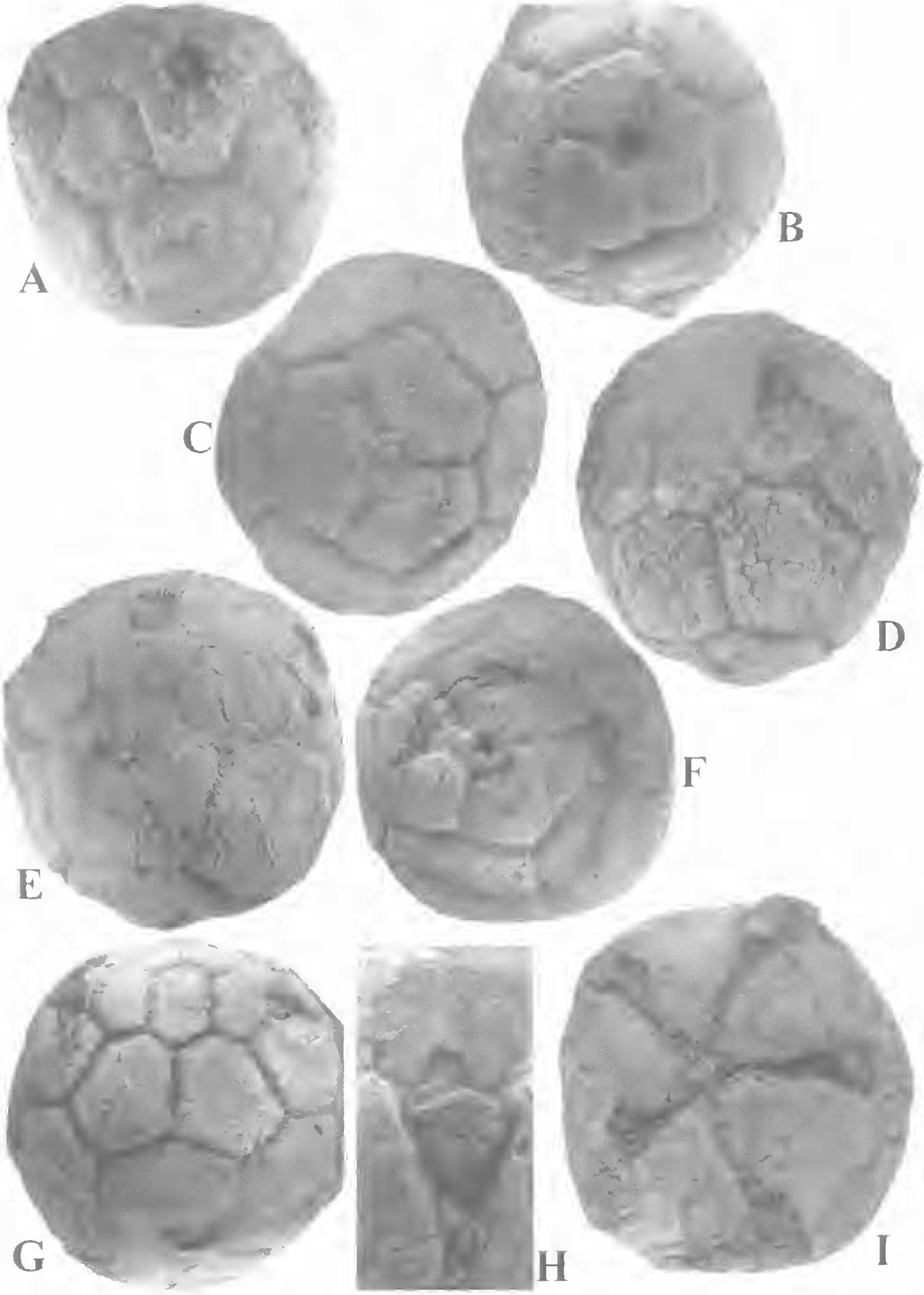



FIG. 7. *Wacrinus caseyensis* gen. et sp. nov. all from NMVPL1931. A,B, A ray and basal views of NMVP100278, ×4.5. C-E, basal, C radial and A radial views of NMVP100279, ×3. F, G, I, basal, C-D interray and oral views of holotype NMVP100280, ×2. H, radial facet of NMVP100281, ×4.5.

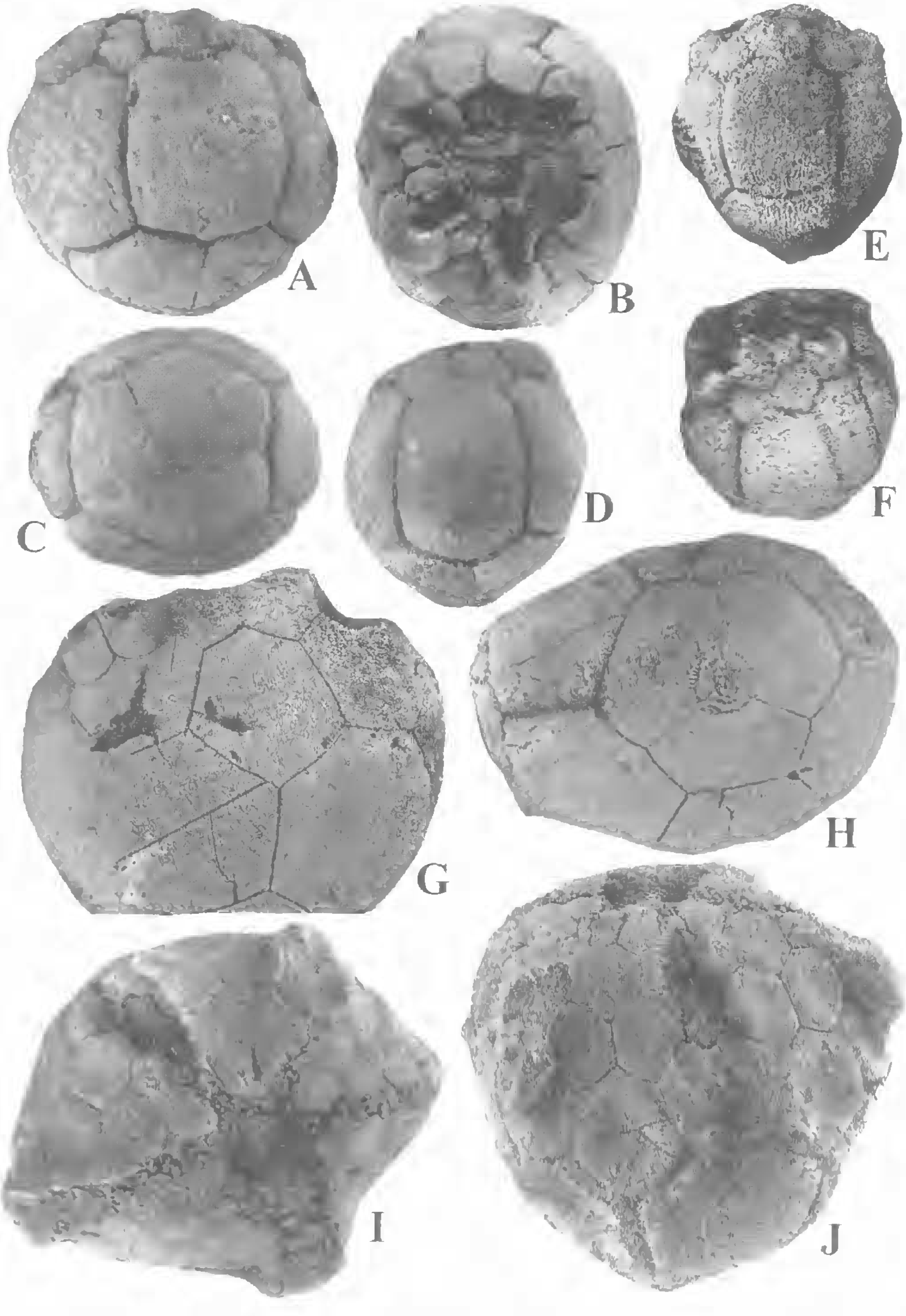



FIG. 8. *Wacrinus caseyensis* gen. et sp. nov. all from NMVPL1931. A-D, B radial, distal, proximal and C-D interray views of NMVP100282, ×5. E,F, A radial and C-D interradial views of WAM91.719, ×2.5. G,H, B ray and proximal views of NMVP100283, ×3. I,J, distal and E ray views of NMVP100284, ×4.

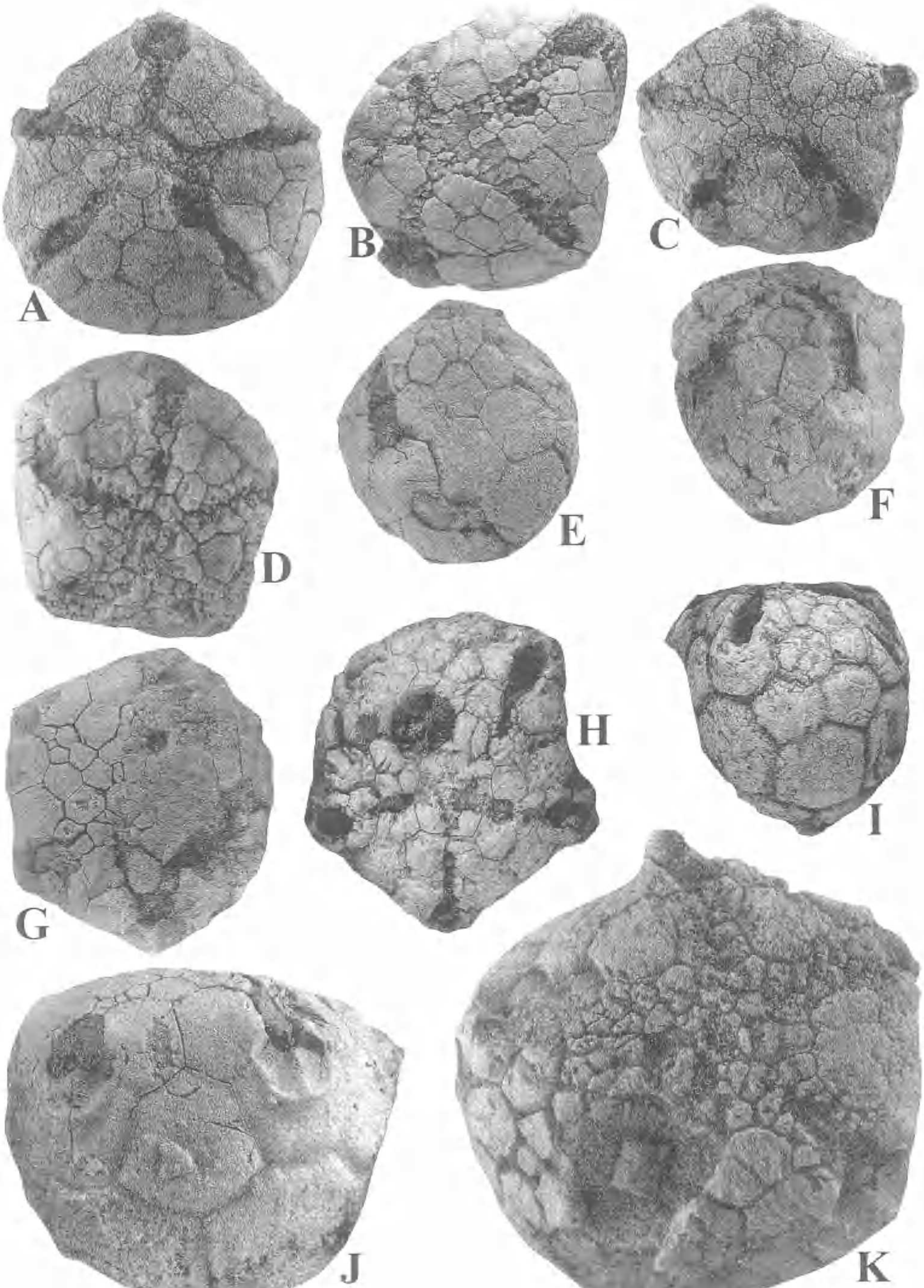



FIG. 9. *Wacrinus caseyensis* gen. et sp. nov. all from NMVPL1931. A-C, distal views of thecae. A, NMVP100272, ×1.8. B, NMVP100273, ×2.3. C, NMVP100274, ×1.8. D-F, distal and D-E and E-A interradial views of NMVP100275, ×1.8. G, J, distal and A-B interradial views of NMVP100276, ×1.8 and ×2.7, respectively. H, I, distal and C-D interradial views of QMF36180, ×1.8. K, distal view of NMVP100277, ×2.7.

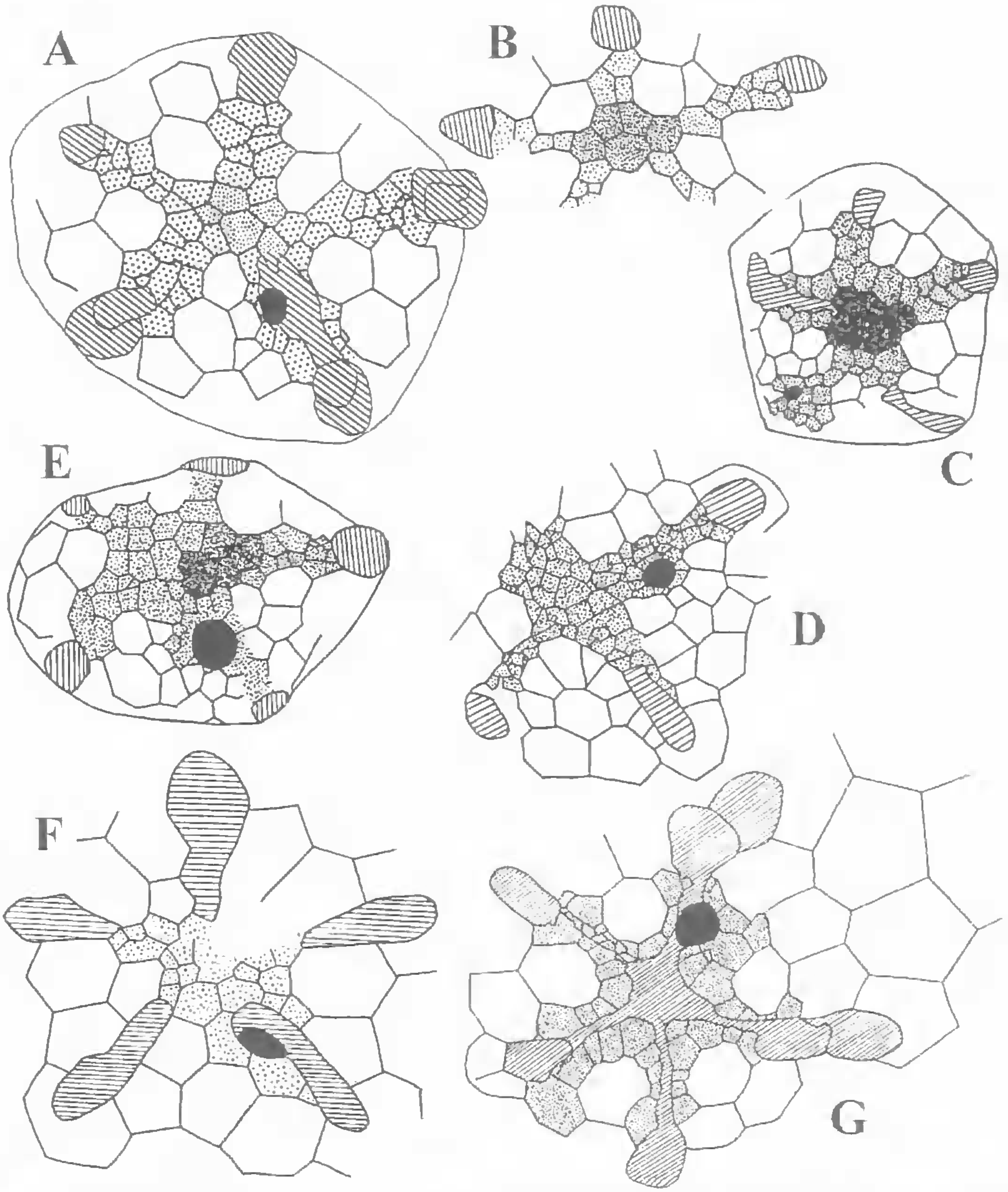
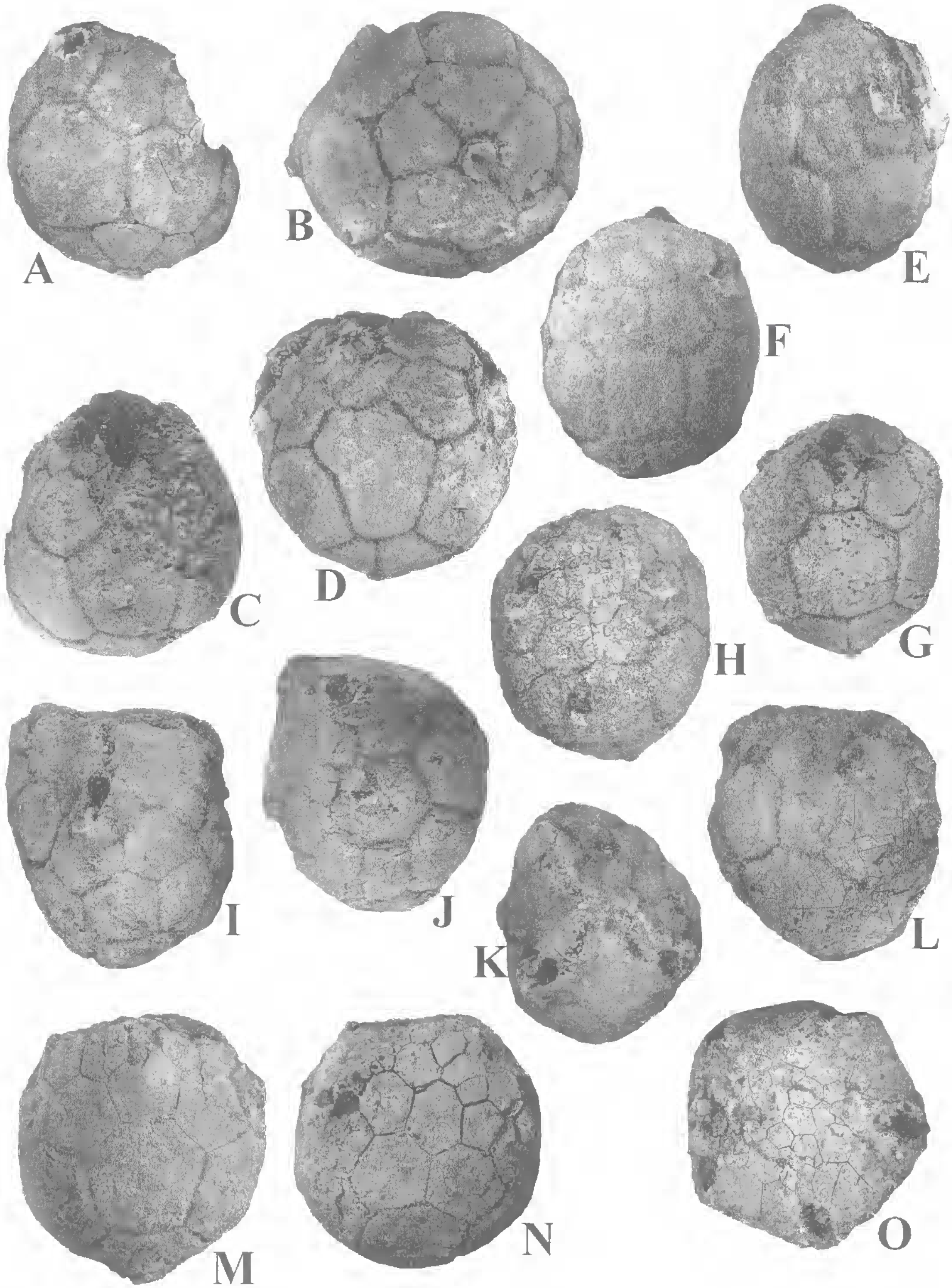



FIG. 10. *Wacrinus caseyensis* gen. et sp. nov. Camera lucida sketches of tegmens. Black = anal opening; lined = nonpreservation (as in arm bases and ambulacral tracts); light stiple = ambulacral plates (apparently thinner than interambulacrals because they weather more easily); heavy stiple = orals (5). A, NMVP100274 (Fig. 9C). B, NMVP100285. C, NMVP100275, (Fig. 9D). D, NMVP100273 (Fig. 9B). E, NMVP100286. F, NMVP100272 (Fig. 9A). G, NMVP100280 (Fig. 7I).

distally supporting 2 then 1 interambulacrals of variable size. Tegmen short, of many plates, plates well differentiated into ambulacrals and interambulacrals; ambulacrals usually small, forming 2 parallel series from each arm base to oral pole, with considerable variation in size and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intercalation of small accessory plates, usually with 5 central interradial orals, with AB and EA orals in contact with the large interambulacral but BC and DE orals separated from interambulacrals by ambulacral plates; interambulacrals normally 1 (but sometimes 2 or 3) large plate in each interray except CD, several in CD interray of variable size and arrangement and also variable adjacent to anal opening; anal opening through tegmen without anal tube, situated in ambulacral plates of C ray halfway between arm base and oral pole, surrounded by tiny plates on all sides (generally weathering quickly so that details are rarely available). Stem of short columnals, with narrow areola and well-developed narrow marginal crenularium; diameter of stem apparently increasing distally.

*Morphogeny.* A well-preserved cup 10mm long indicates changes which accompanied growth to the average sized individuals (about 20mm long) and to the rare large individuals up to more than 30mm long. The major feature of growth is that the size of plates distal to the radial circlet which were tiny in the small individual increased in size relative to the basal and radial plates. Whereas in the small individual the 1st interbrachial is 1/6 length of the radial, in a theca only 13mm long this ratio had risen to 1/2 and in the largest theca to almost 5/6. Corresponding increases in relative sizes of brachial and tegminal plates are also apparent. Most of the tegminal plates have weathered off but the remnants of large interradial (presumably the large interambulacral) plates suggest that the ambulacral series was well-differentiated in the smallest individual as they are in the 13mm theca. It appears that at 10-20mm cup length, basals and radials grew at only 1/2 the rate of more distal plates.

Brower (1967) noted a similar change in relative growth rates in acrocrinitids: principally the radial plates which grew rapidly in earliest growth gradually assume a slower growth rate as more distal cup plates experience increased growth rates.

REMARKS. The thecae have weathered out of dark red silty beds that approach a coquina at some levels; they are scattered over the surface and are weathering continuously so perfect specimens are almost unknown. In most cases the first plates to weather are the small ambulacrals giving the tegmen the very obvious 5-rayed appearance.

The large collection of some 100 thecae gives a good understanding of intraspecific variation. Almost all this variation appears to be confined to the tegminal plates; certainly there is no variation in the basal or radial circlets. As already mentioned in the description, the number and arrangement of second row interbrachials and interambulacrals have a few variations but in <10 specimens whereas the variation in size, shape and arrangement of both ambulacral and CD interambulacral plates is much more widespread.

Several aberrant individuals are known; one has 4 basals (Fig. 11B), 7 plates in the radial circlet (Fig. 11B), a peculiarly shaped 7-sided E radial (Fig. 11D) and asymmetrical tegmen (Fig. 11A). It appears the anterior interprimibrach is forced into the radial circlet, contacting the basal circlet and demanding an extra side to that circlet; the strange E radial appears to be a fusion of 2 plates, the radial and a second row interbrachial of the anterior interradius which is moved proximally with the 1st interprimibrach. It is not clear how this aberrant growth came about as injury is not evident and there is no evidence of disease or parasitism. Another specimen has only 3 ambulacral tracts on the tegmen and thus only 3 arms (Fig. 11K); in the radial circlet between A and D radials it has 2 plates that do not lead into normal arm bearing rays (Fig. 11J); it has 3 anal plates resting on the primanal (Fig. 11L) as opposed to the normal 2. Again the cause of this aberrancy is unclear although regrowth after a predatory removal of 2 arms at an early growth stage might be expected.

### **Wacrinus millardensis** sp. nov.
(Figs 12,13)

ETYMOLOGY. For Millard Creek adjacent to the type locality.

MATERIAL. HOLOTYPE: QMF36190. PARATYPES: QMF36191-36193, WAM91.715, 91.716, 91.718, 91.720, 91.721 all from QML1030 above Casey Falls.

DIAGNOSIS. Cup small (up to 18mm long), basals and radials with large irregularly spaced tubercles and median ray ridges; 1st primibrach

FIG. 11. *Wacrinus caseyensis* gen. et sp. nov., all from NMVPL1931. A-D, lateral B ray, proximal, lateral D ray and lateral E ray views of aberrant cup GSWA19390, ×1.5. E, F, lateral D-E interray and posterior views of WAM91.722, ×2. G,H, lateral B ray and posterior views of GSWA19391, ×1.5. I-L, lateral B ray, lateral D ray, distal and posterior views of aberrant, 3-armed, cup GSWA19392, ×1.5. M,N, anterior and posterior views of WAM91.723, ×2. O, distal view of GSWA19393, ×1.5.

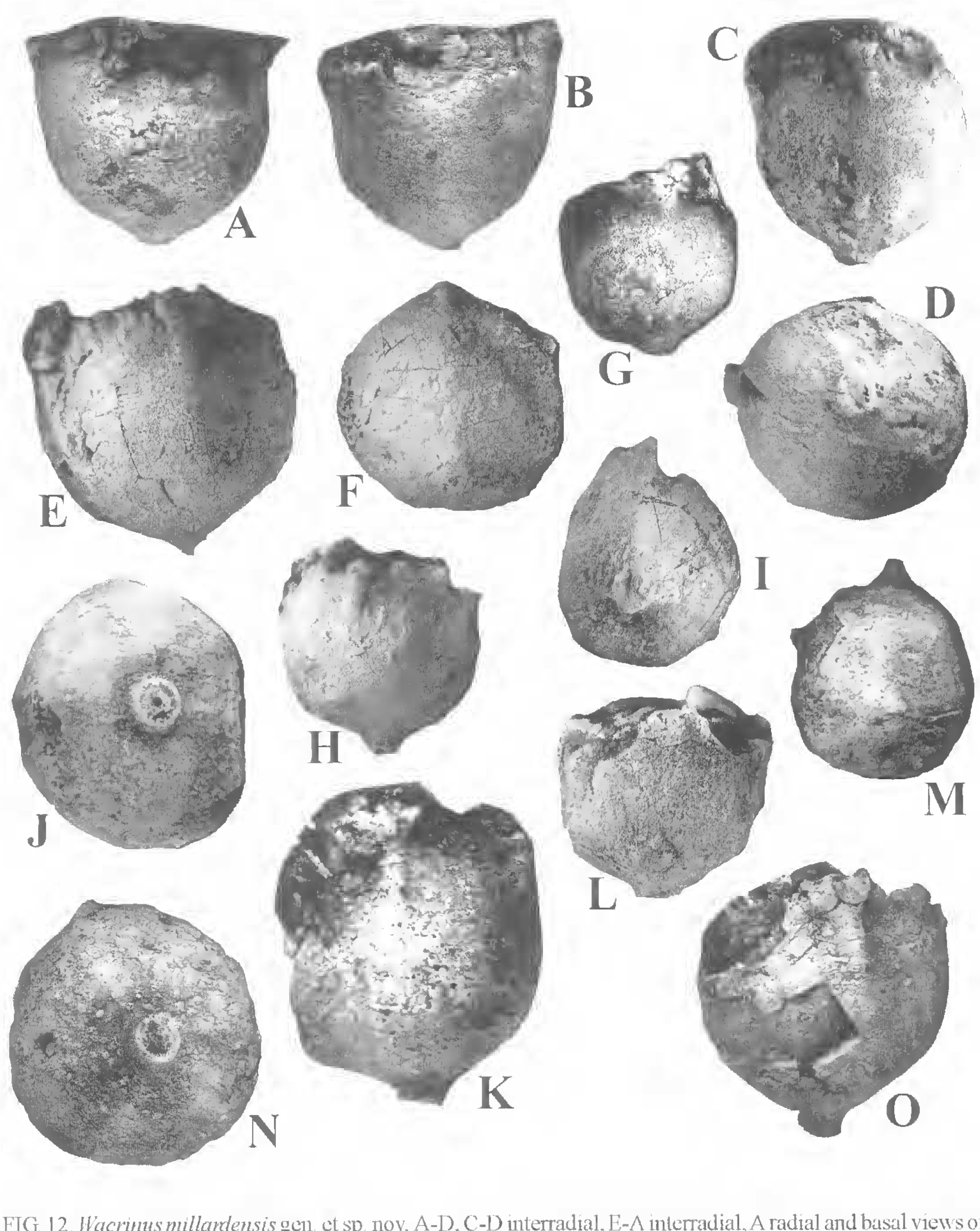


FIG. 12. *Wacrinus millardensis* gen. et sp. nov. A-D, C-D interradial, E-A interradial, A radial and basal views of holotype QMF36190, ×2. E-H, Lateral views of WAM91.721, WAM91.718, WAM91.715, WAM91.716, ×2. I, Basal view of WAM91.720, ×2. J, K, Basal and lateral views of QMF36191, ×2.5. L, M, Lateral and basal views of QMF36192, ×2.5. N, O, Basal and lateral views of QMF36193, ×2.

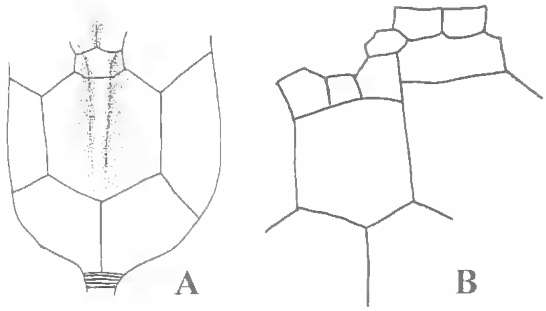



FIG. 13. *Wacrinus millardensis* gen. et sp. nov. Camera lucida sketches of plate arrangement. A, A ray view of cup showing shape of 1st primibrach and position of ray ridge (drawn from WAM91.721, Fig. 12E). B, posterior interray (C radial surmounted by axillary 1st primibrach and 2 secundibrachs on right) showing primanal supporting 3 plates distally (drawn from QMF36190, Fig. 12A).

transversely subrectangular, fixed in theca, axillary, with 2 distal curved sides (at interbrachial sutures) meeting in middle of ray in sharp point; 1st secundibrach fixed in cup; interprimibrachs large, 1 per interray, with smaller tegminal plates distally, extending just proximal to primibrachs with obtuse angle between distal margins of adjacent radials; stem round in section, with small diameter relative to theca.

DESCRIPTION. Cup high bowl-shaped, with elongate convex base. Narrow ray ridges most prominent on primibrachs and distal part of radials, extending to stem facet in some specimens. Hexagonal basal circlet of 3 equal plates, with sutures in B and E rays and C-D interray. Radials 5, large, convex, 6- (A, C and D radials) or 7-sided (B and E radials), with wide horizontal distal suture to primibrach; radial facet angustary. First primibrach subrectangular to pentagonal, axillary, with Y-shaped ray ridge dividing into the 2 arms, with curved distal margins at interbrachial sutures meeting in sharp point in ray axis. First secundibrach fixed in cup, with broad deep groove on distal side and fine central canal piercing the plate medially beneath the groove. Remainder of arms unknown. Primibrachs and 1st secundibrachs sutured to interbrachial plates. Primanal about same size as radials, supporting 3 plates distally (smaller central and equal laterals). Interbrachials 1 per interradius, large, abutting primibrach and 1st secundibrach, extending proximally between radials by distance equal to length of primibrach giving proximal margins a junction at about 120°. Tegmen unknown. Ornament on cup of coarse tubercles, becoming less obvious with growth, organised into colinear lines with margins in few specimens (most often removed by weathering). Stem slender, of very short columnals, with circular, flat attachment facet, pierced centrally by extremely fine axial canal.

REMARKS. This species does not reach the size of *W. caseyensis* and differs in having ray ridges, relatively small axillary primibrach with distal pointed tip and distinct cup shape (subcylindrical in distal part and slightly elongate base).

Suborder GLYPTOCRININA Moore, 1952
Superfamily MELOCRINITOIDEA
d'Orbigny, 1852
Family MELOCRINITIDAE d'Orbigny, 1852

**Melocrinites** Goldfuss, 1831

TYPE SPECIES. *Melocrinites heiroglyphicus* Goldfuss, 1831 by subsequent designation of Roemer, 1855 from the Upper Devonian of western Europe.

**Melocrinites solidus** sp. nov.
(Figs 14-17)

ETYMOLOGY. Latin *solidus*, thick, entire.

MATERIAL. HOLOTYPE: WAM91.703. PARATYPES: QMF36194-36196, WAM91.701 all from QML1029, in Millard Creek just W of Casey Falls.

DIAGNOSIS. Radials making up large part of thecal length; 1st primibrach usually hexagonal, with 2 distal lateral margins narrow and distal central margin concave proximal to the arms, often axillary; 2nd primibrach very short, axillary; arms (2 per ray) fused into a solid trunk, with secundibrach 2 axillary (and giving off the first auxilliary arm (of Kesling, 1964)); more distal arms arising slightly irregularly but from about every 5th or 6th brachial; tegmen of few (c. 10-14) large plates; interprimibrachs few, 1st in contact with radial and 1st primibrach, 2nd row of 2 between arms butting up to tegmen plates. Plate arrangement irregular in some specimens. Ornament of vermiform ridges highly variable from barely evident to dense over whole plates.

DESCRIPTION. Cup of medium length (up to 30mm; mainly 20-25mm), from short (e.g. 20mm long and 20mm diameter) to long (e.g. 27mm long 19mm diameter) conical; surface of plates smooth to highly ornamented, varying between plates of 1 individual and between individuals; ornament of vermiform ridges and isolated tubercles, often reaching sutural margins in basals and radials but usually with a smooth marginal zone particularly on tegmen. Basal

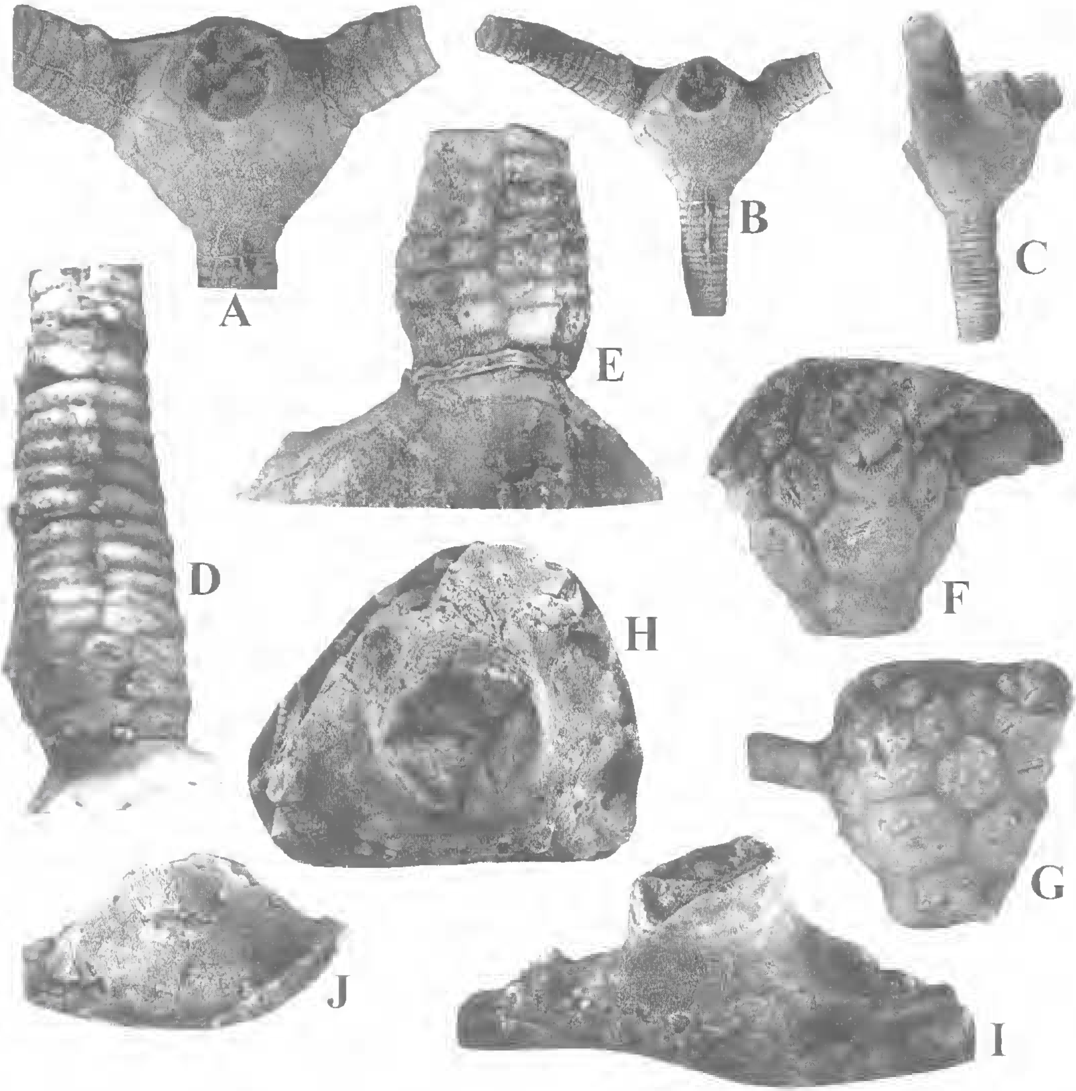



FIG. 14. *Melocrinites solidus* sp. nov. all from QML1029. A-E, QMF36196. A-C, lateral views, ×1.5, ×1 and ×1, respectively. D,E, arms viewed from underside, showing fused columns of the 2 arms, ×3. F,G, lateral views of juvenile WAM91.701, ×2. H,I, holdfast in plan and lateral views QMF36197, ×1. J, lateral view of holdfast QMF36198, ×1.

circlet of 4 plates, with interplate sutures positioned variably (B, C, D and A (QMF36195) or E (QMF36194) rays; basals pentagonal, up to 6mm long in lateral view, together forming circular stem facet proximally; stem facet flat, with irregular crenularium about 1/3 stem radius around margin, with medium sized axial canal, with slight indentations at sutures. Radials 5, contiguous, up to 10mm long and wide, 6-sided, or 7-, depending on position over 1 or 2 basals. First primibrach 6-sided, with horizontal suture against radial, with distal margin curved proximal to arm, with widest point distal to midlength. Second primibrach short, pentagonal, axillary, with short distal central peak, not present in every ray (Fig. 14A, B). Secundibrachs all short, suturally fused to those of other arm in same ray, with zigzag or straight junction between 2 arms in different places. Second secundibrach axillary, giving rise to short stumpy auxilliary arm. Distally every 5th, 6th or 7th brachial axillary, giving off stout arm vertically. Each ray trunk constricted at junction with theca, of greatest diameter at about 2nd or 3rd

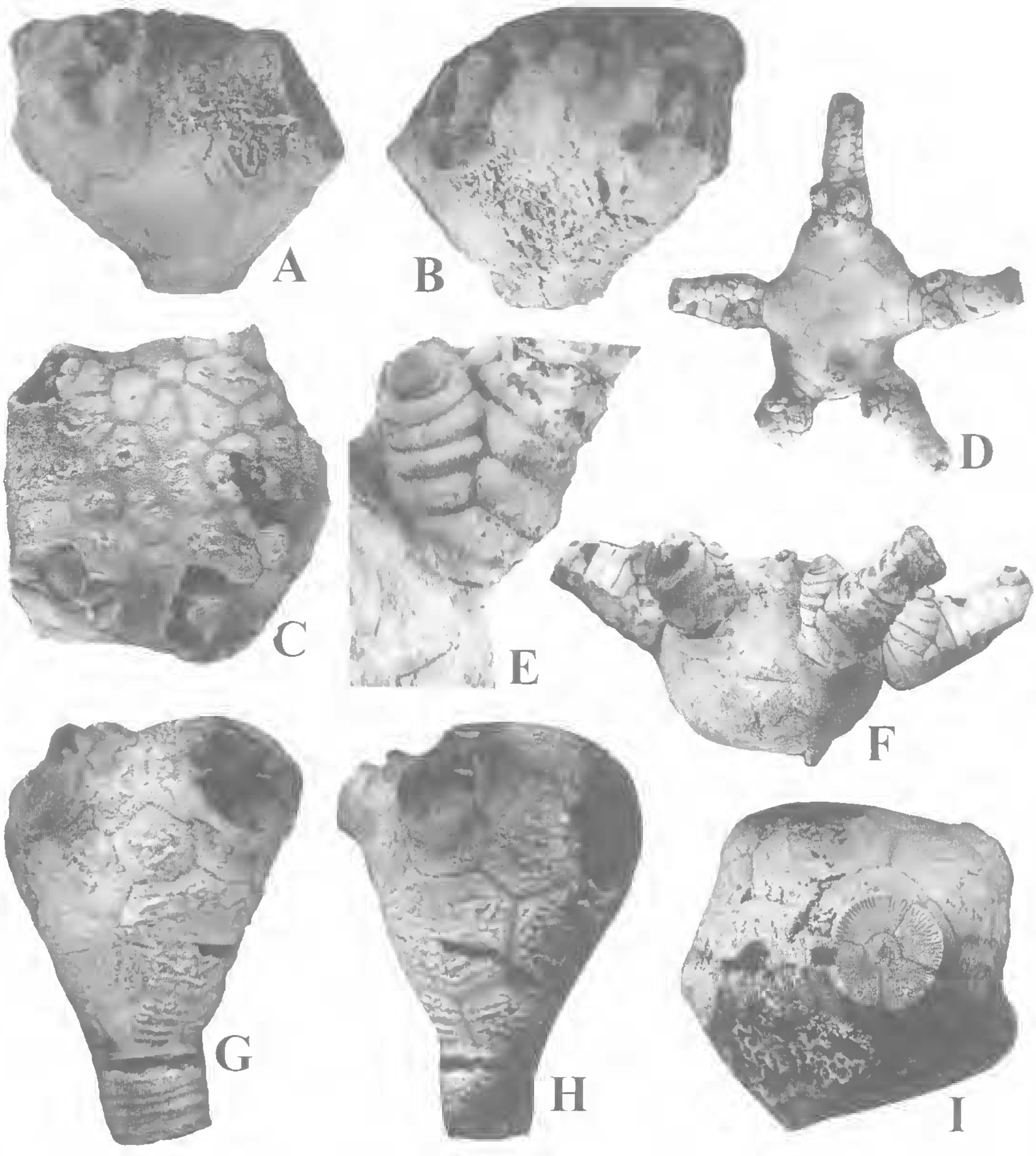



FIG. 15. *Melocrinites solidus* sp. nov. all from QML1029. A-C, Two lateral and tegminal views of QMF36194, ×2. D-F, Holotype WAM91.703. D, Tegminal view, ×1. E, lateral view of base of arm showing axillary second primibrach, ×3. F, Lateral view in C-D interray showing anal tube, ×1.5. G-I, Two lateral and a basal view of QMF36195, ×2.

secundibrach, with food groove completely sealed above by small convex irregular cover plates, pierced by large elliptical canal nearer to cover plates. Interbrachial facets covered with long anastomosing culmina and crenellae indicating immovable ligamentary junctions. Interprimibrachs few; 1st interprimibrach hexagonal, resting on radials, supporting 2 high

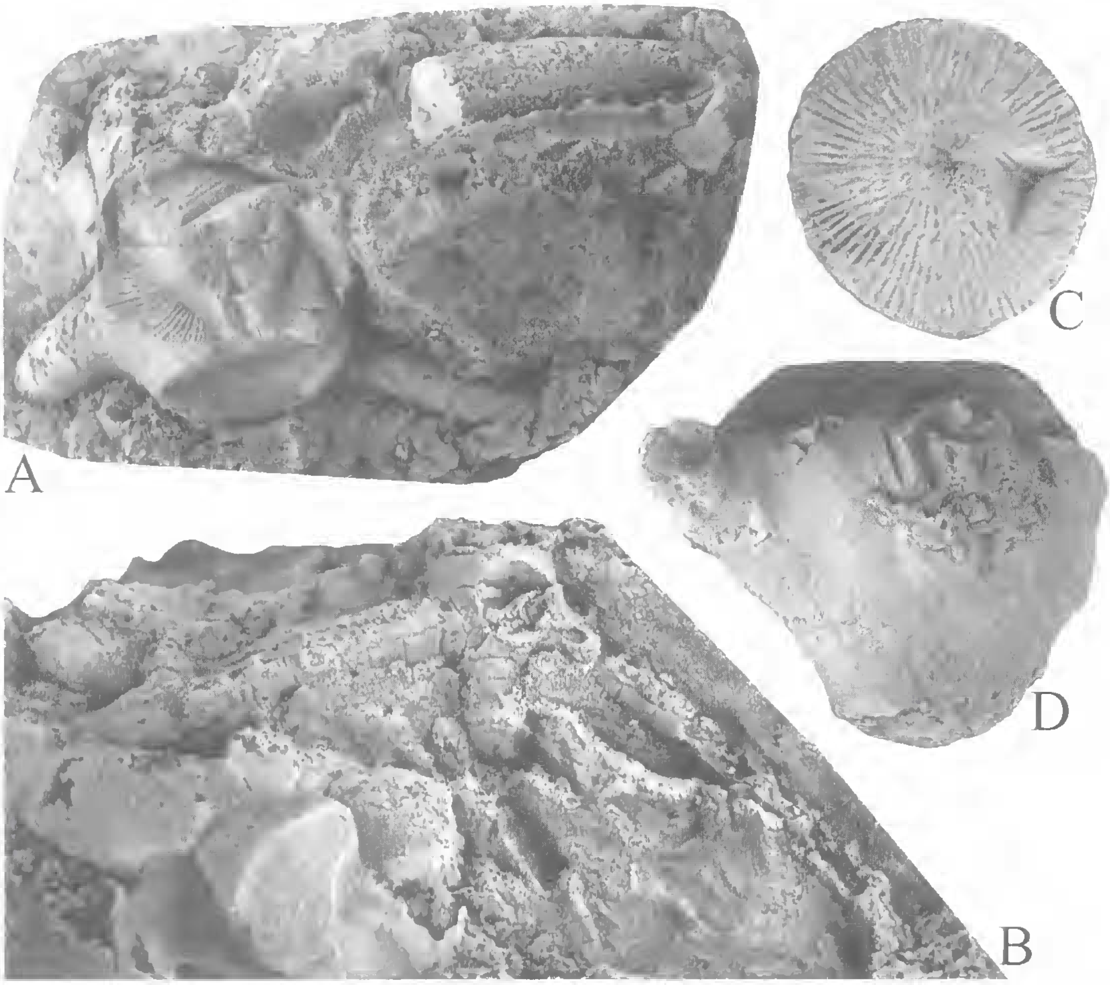


FIG. 16. *Melocrinites solidus* sp. nov. all from QML1029. A, proximal view of strongly rooted holdfast QMF36199, ×3. B, lateral view of strongly rooted holdfact QMF36200, ×2.5. C, end view of piece of stem showing extensive crenularium QMF36205, ×3. D, lateral E ray view of cup QMF36206, ×1.5.

plates in next row between arm bases; 2nd row reaching tegmen plates. Intersecundibrachs absent. C-D interray variable in available specimens; primanal supporting 2 or 3 plates distally; in WAM91.703 primanal apparently made up of 2 pentagonal plates with slight constriction at their junction. Stem circular in section, of large variable diameter up to 10mm; short columnals with row of pointed tubercles at midlength; with ligamentary articulation having wide marginal crenularium. Aureola wide on facet at base of cup but very narrow distally. Crenula dividing once or twice near midradius of facet.

REMARKS. This species is most closely allied to the Upper Devonian species of western Europe. The type species, *M. heiroglyphicus* Goldfuss, which occurs in the Frasnian of Germany, Belgium and England has similar plate ornament, cup shape and other general proportions. However, the new Australian species is distinguished by the shape of its first primibrach, the fewer plates in its tegmen and all secundibrachs being free of the cup. These features also distinguish the other Upper Devonian species of the Kuzbass (Dubatalova, 1964) and northern Canada (Springer, 1920). The new species is also distinguished from the 2 Middle Devonian species from eastern Australia (Jell et al., 1988) by its free secundibrachs and shape of its axillary primibrach. None of the known North American species have the combination of ornament, free secundibrachs,

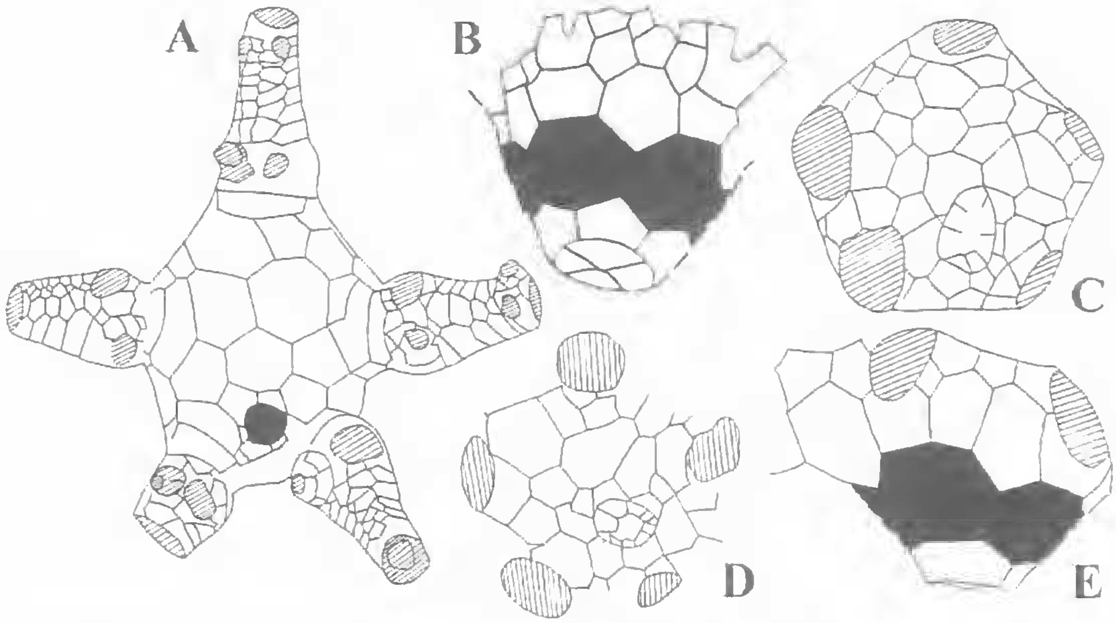



FIG. 17 *Melocrinites solidus* sp. nov. Camera lucida sketches. A, distal view of tegmen of WAM91.703 (Fig 15D-F): solid black = anal tubercle, lined = fractured arm extremities and bases of ramules, in some areas (e.g. CD interray) sutures not evident. B, posterior oblique view of small cup showing 4 basals, primanal supporting 3 anals WAM91.701 (Fig 14F, G), solid black = radials. C, distal view of tegmen of QMF36195 (Fig. 15G-I): lined = broken arm bases, oval ringed on inner side by small plates = anal tubercle. D,E, QMF36194 (Fig 15A-C); lined = broken arm bases, solid black = radials. D, distal view of tegmen with anal tubercle at lower centre. E, lateral view showing aberrant interray with 2 interprimibrachs in proximal row and normal interray to left.

few tegmen plates and 1st primibrach shape seen in the new Australian species. While the large number of existing specific names applied in this genus is an incentive to avoid creating more this species is quite distinctive and requires specific recognition.

Subclass DISPARIDA Moore & Laudon 1943
Superfamily PISOCRINOIDEA Angelin, 1878
Family PISOCRINIDAE Angelin, 1878

**Jaekelicrinus** Yakovlev, 1949

TYPE SPECIES. *J. bashkiricus* Yakovlev, 1949 from the Frasnian of Bashkiria; by original designation

REMARKS. Rozhnov (1981) reviewed the genus, described in detail the type and the only other species assigned, *J. yakovlevi* Rozhnov, 1981, and provided numerous plate diagrams for both species. He distinguished the genus from its ancestor *Calycanthocrinus* Follman, 1887 by the greater number of pararadials (12-23) and thicker calical plates.

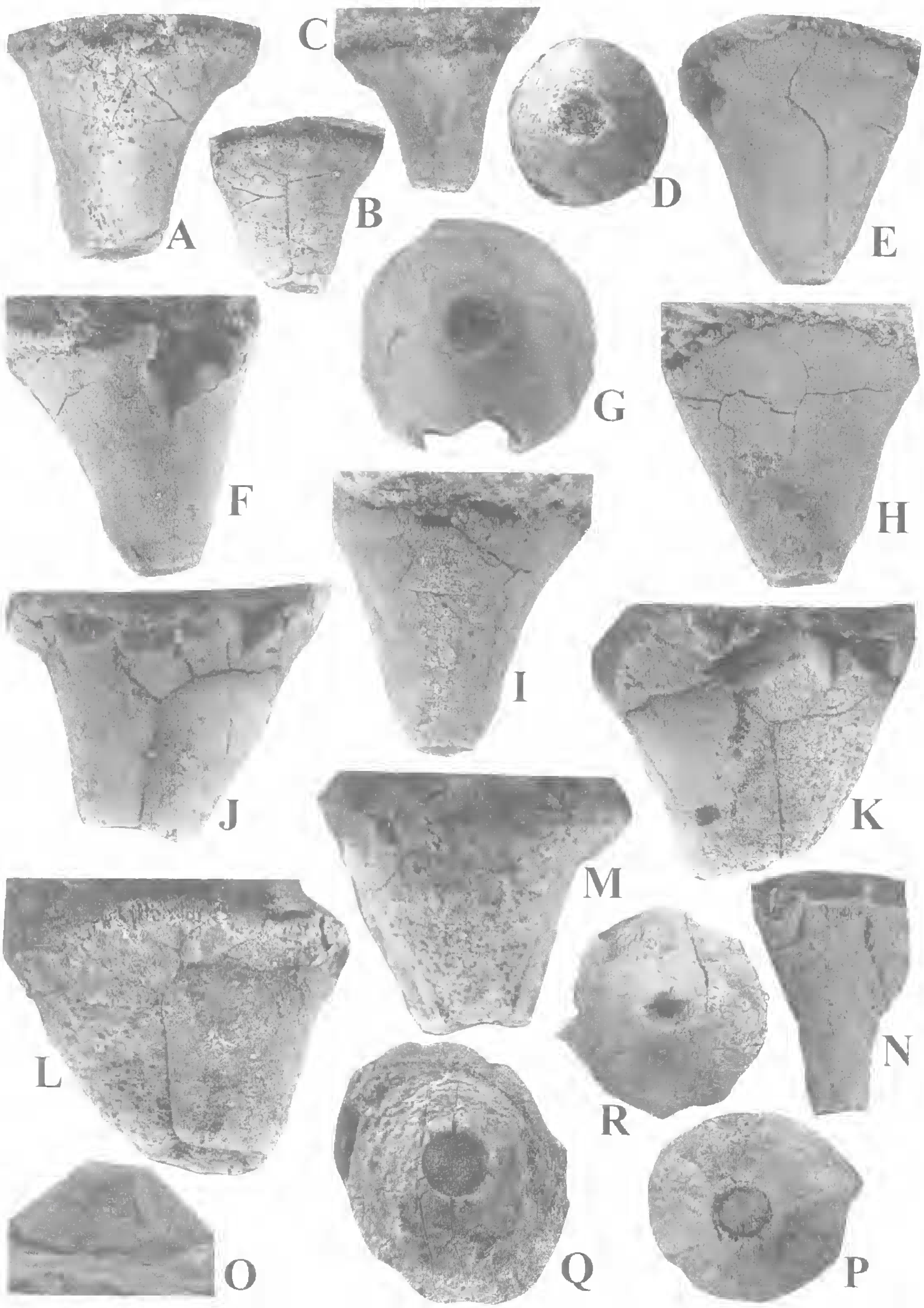
**Jaekelicrinus murrayi** sp. nov.
(Figs 18-20)

ETYMOLOGY. For Dr Peter Murray, Northern Territory Museum who greatly facilitated collecting this material.

MATERIAL. Holotype: NMVP100308. Paratypes: NMVP100301-100304, 100308-100310 all from NMVPL1936, S of the Teichert Hills.

DIAGNOSIS. Basals 3, unequal, with largest basal having peaks at both distal corners and situated proximal to A radial, with some variation in course of suture between basals and radials; pararadials 12.

DESCRIPTION. Cup up to 12mm long, high conical or with slight lateral bulge in A ray producing suboval section, with marked increase in diameter at distal margin of radial circlet due to strong flaring of pararadial plates in some specimens. Base of cup with wide concave stem facet. Basals 3, unequal, forming short circlet, with relatively large circular concave stem facet pierced by small rimmed median canal; largest basal with peaks on both distal corners and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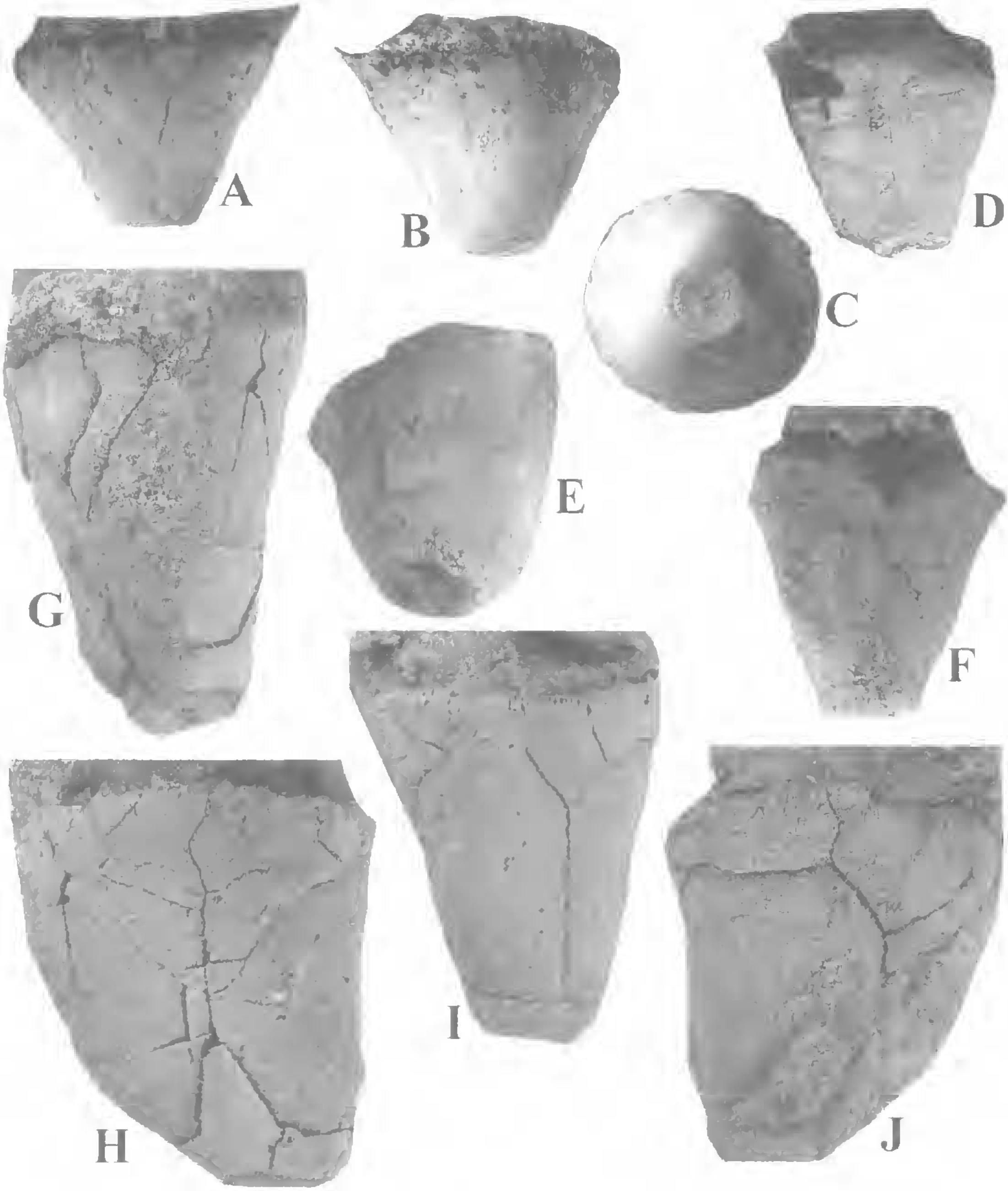


FIG. 19. *Jaekelicrinus murrayi* sp. nov. A-C from QML1029; D-J from NMVPL1936. A-C, lateral views except basal view C of QMF36201, ×5. D, lateral view of QMF36202, ×3. E, F, lateral views of NMVP100309, 100310, ×5. G-J, lateral views of holotype, NMVP100308, ×4.

FIG. 18. *Jaekelicrinus murrayi* sp. nov. A-M from NMVPL1936; N-R from QML1951. A-E, lateral views except D a proximal view of NMVP100301. A, C, E, ×4. B, x3. D, ×2.5. F-I, lateral views except G a proximal view of NMVP100302, ×6. J-M, lateral views of NMVP100303, ×5. N, lateral view of NMVP100304, ×4. O,P, lateral and plan views of holdfast NMVP100305, ×2. Q, R, plan views of holdfasts NMVP100306, 100307, ×2.

situated proximal to A radial, with sutures separating other basals situated proximal to B infraradial and D radial; 2nd largest basal with peak on only 1 distal corner, proximal to D radial, with suture to smallest basal proximal to B infraradial; smallest basal proximal to B infraradial. Radials of 2 distinctly different sizes; A and D very large, occupying nearly 2/3 of cup, variable in shape but usually widening distally then contracting markedly where pararadials intervene and expanding again just proximal to single radial facet; B, C and E radials small of highly variable size, often impossible to distinguish from pararadials, each with single radial facet; B infraradial nearly as large as A and D radials and occupying nearly 1/3 of cup, of variable shape; pararadials 12, of highly variable shape, size and arrangement, each with single radial facet, often very difficult to distinguish from smaller radial plates particularly E radial; radial facets occupying almost full width of plate but leaving very narrow vertical projections laterally at sutural margins, with characteristic vertical grooves within the plate just proximal to the facet in slightly weathered specimens.

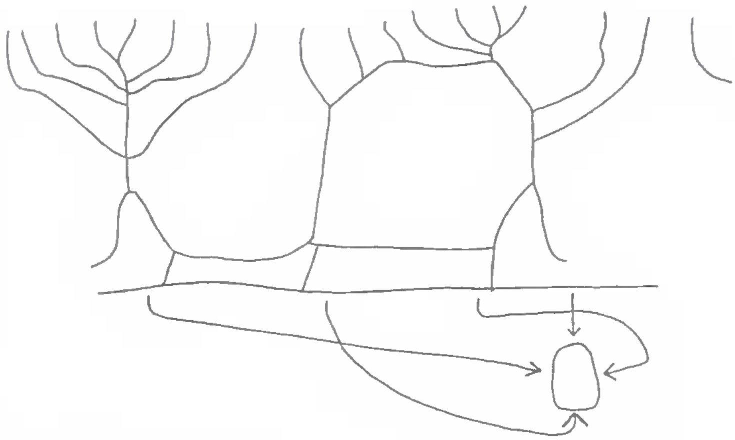

FIG. 20. *Jaekelicrinus murrayi* sp. nov. Camera lucida sketch with indication of which sides of cup are illustrated where; interplate suture at far right is same as that at far left; upper margins of radials and infraradials not shown: NMVP100308 (Fig. 19G-J).

REMARKS. This species is most closely related to the type species from which it may be distinguished by the 3 unequal basals, the E radial being so similar to the pararadials and the number of radial plates between A and D radials through E ray compared to single pararadial between A and B radials. It may be distinguished from *J. yakovlevi* Rozhnov, 1981 from the Frasnian of Bashkiria by the fewer paradials, the different situation of the various sized basals and the relatively undifferentiated E radial. *J. murrayi* must be considered a descendant of *J. bashkiricus* on a separate lineage from *J. yakovlevi*. The enormous amount of variation mentioned in the description of these few specimens is such that the possibility of *J. bashkiricus* and *J. murrayi* belonging to one species cannot be overlooked. However, the arrangement of plates rather than their shape and size is probably distinctive. Larger populations of both species will be necessary to be certain of this distinction. The highly variable nature of the cups available, also makes biometric studies useless until larger collections are available.

## **Playfordicrinus** gen. nov.

TYPE SPECIES. *Playfordicrinus kellyensis* sp. nov.

ETYMOLOGY. For Dr Phillip Playford for his contribution to understanding of the Devonian of the Canning Basin.

DIAGNOSIS. Cup subspherical, with widely spaced fine granular ornament. Basals 3, irregularly shaped, each asymmetrical with a distal projection at sutures between radials. Radials (or inferradials) 3, large, making up most of the cup; arm-bearing plates variable in number (7-14), with lateral projections distally; articulating facets flat, radially serated in some specimens (probably due to weathering); pararadials 2-9.

REMARKS. Rozhnov (1981) provided a thorough analysis of the Pisocrinidae in which 2 lineages lead from spherical, low bowl-shaped or low conical *Pisocrinus* with 5 basals to high conical forms with 3 basals, the latter occurring in the Upper Devonian. The lineage leading to *Jaekelicrinus* through *Trichocrinus* and *Calycanthocrinus* is the only one developing pararadials. *Playfordicrinus* also has pararadials and 3 basals but retains the subspherical shape of *Pisocrinus*. It can not be considered part of the *Jaekelicrinus* lineage because that lineage had achieved and stabilised its high conical thecal shape before developing pararadials and the rest of the lineage retains that thecal shape. Likewise the *Triacrinus* lineage developed a high conical thecal shape in

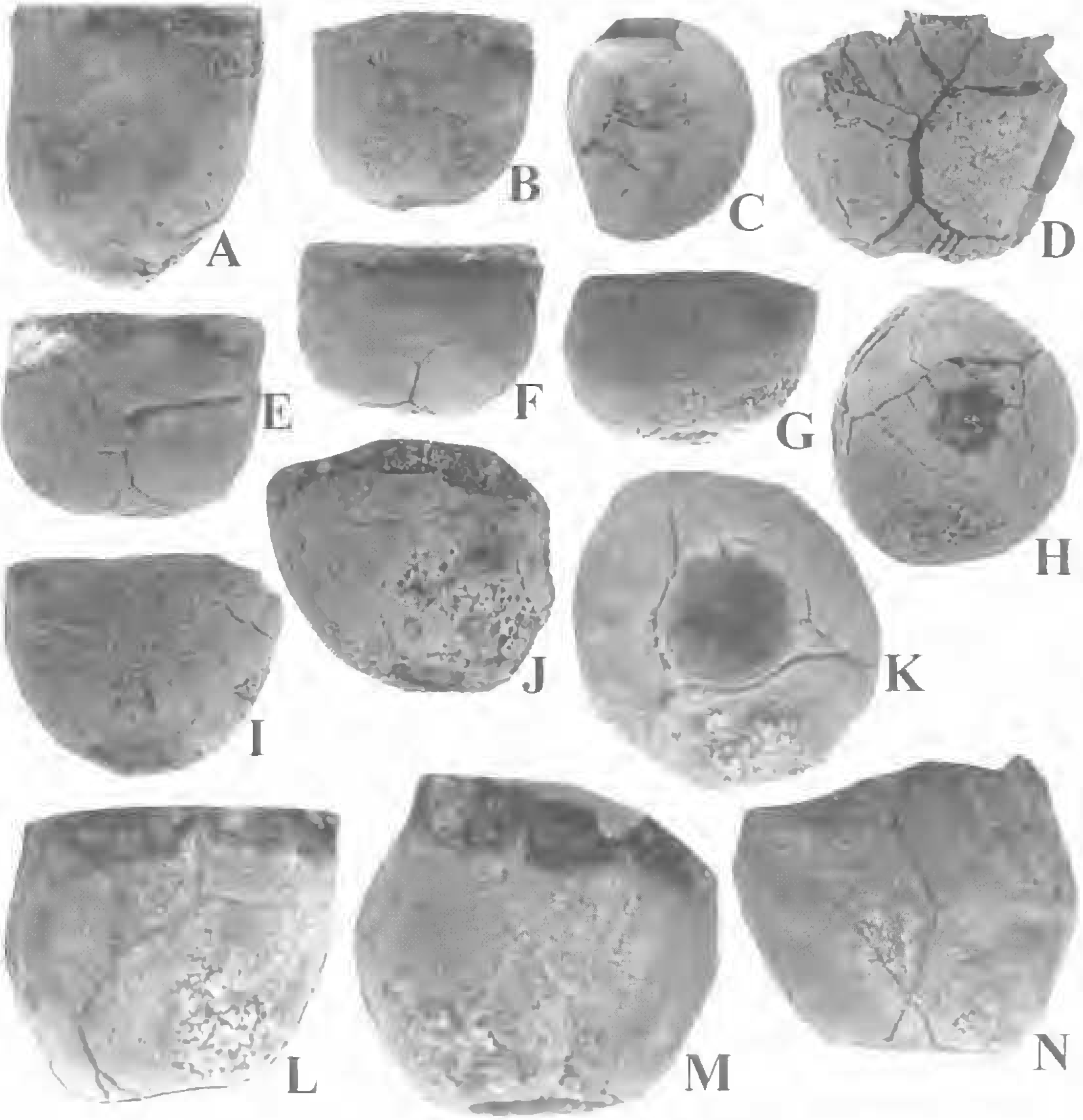


FIG. 21. *Playfordicrinus kellyensis* gen. et sp. nov. all from NMVPL1938. A-D, lateral views except for proximal view C of NMVP100311, ×5, ×3, ×4 and ×5, respectively. E,F-H, lateral views except for proximal view H, of NMVP100312, ×4. I, J, lateral views of NMVP100313, ×4. K-N, proximal (K) and lateral views of NMVP100314, ×5.

the Middle Devonian so *Playfordicrinus* would have to be considered a reversion in thecal shape if attached to that lineage. Cup shape and the fine granular thecal ornament lead us to suggest that *Playfordicrinus* evolved from *Pisocrinus (Granulosocrinus)* in the Middle Devonian and involved the same development of pararadials and reduction to 3 basals as in *Jaekelicrinus* but with retention of the primitive cup shape of *Pisocrinus*. Although our suggestion may not be in accord with cladistic principles because we infer the derived characters of pararadials to have evolved independently twice and reduction in basals from 5 to 3 to have evolved 3 times it is compatible with the phylogeny of the Pisocrinidae as depicted by Rozhnov (1981, fig.9). The new genus is readily distinguished from *Pisocrinus* by its 3 basals and its pararadials

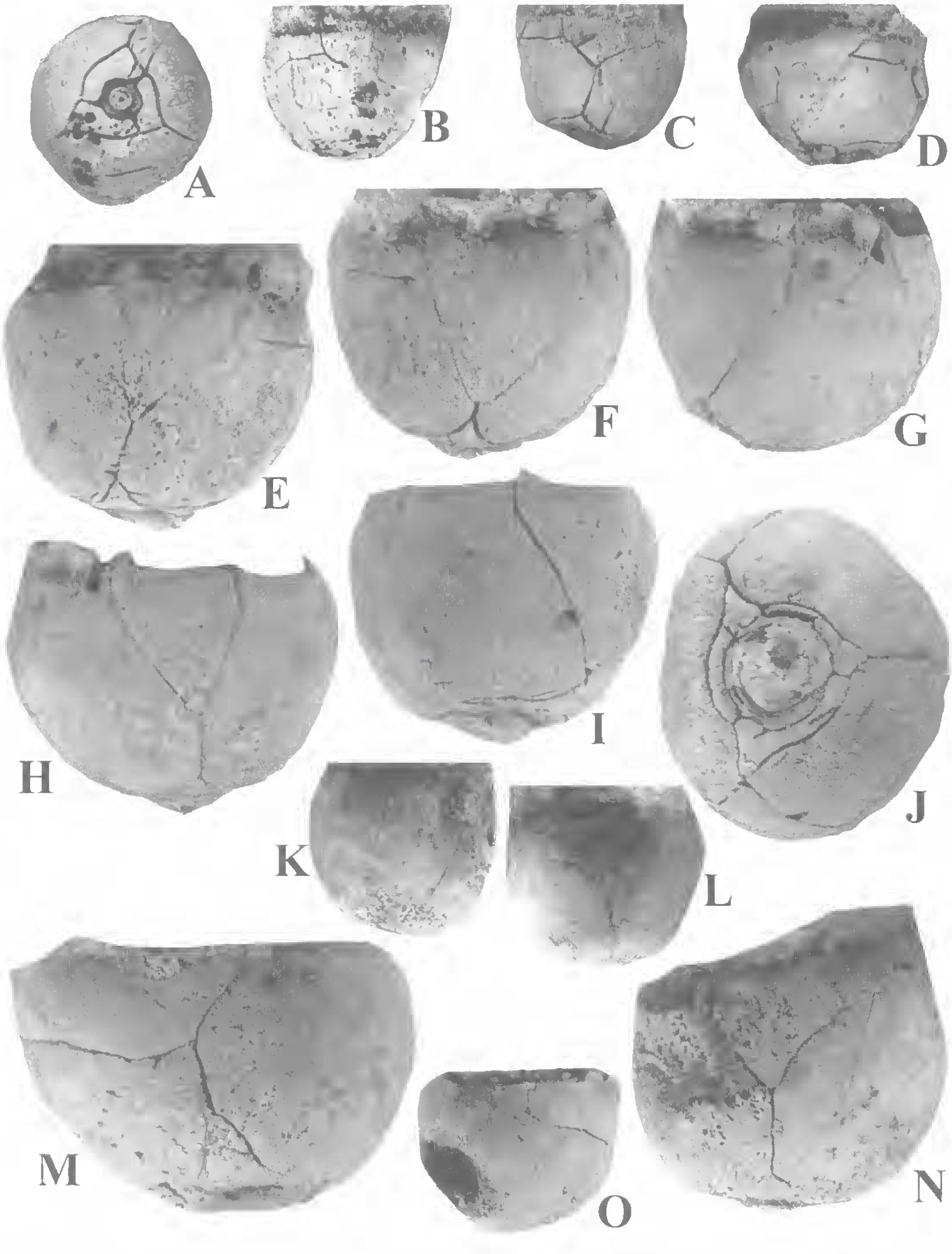


FIG. 22. *Playfordicrinus kellyensis* gen. et sp. nov. all from NMVPL1938 except A-D from NMVPL1936. A-D, proximal (A) and lateral views of QMF36203. A, ×3. B-D, ×4. E-J, proximal (J) and lateral views of holotype NMVP100315, ×8. K, L, N, lateral views of NMVP100316. K, L, ×4. N, ×6. M, O, lateral views of NMVP100317, ×7 and ×4, respectively.

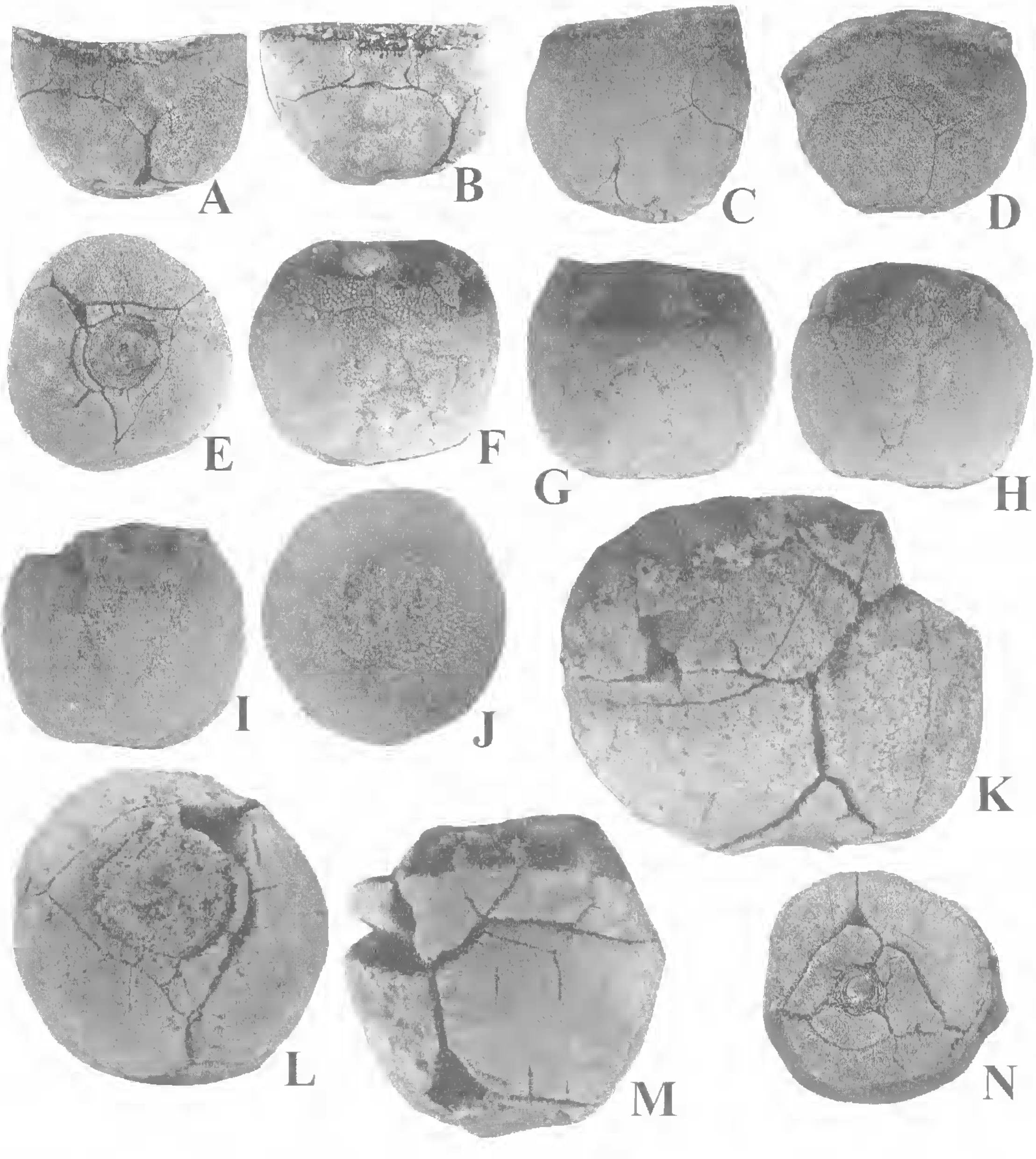


FIG. 23. *Playfordicrinus kellyensis* gen. et sp. nov. all from NMVPL1938. A-E, basal (E) and lateral views of NMVP100318, ×4. E, ×3. F-J, lateral and basal (J) views of NMVP100319, x6. K, N, lateral and basal views respectively of NMVP100320, ×6 and ×3, respectively. L, M, basal and lateral views of NMVP100321, ×6.

and from the other pisocrinids with 3 basals by its subspherical cup. Ausich (1977) and Rozhnov (1981) voiced different opinions on the concept of *Pisocrinus*; the former synonymised *Parapisocrinus* while the latter retained it as a separate genus. This difference of opinion does not affect the discussion (above) leading to erection of a new genus evolving from *Pisocrinus* (*Granulosocrinus*). Settlement of the *Parapisocrinus*

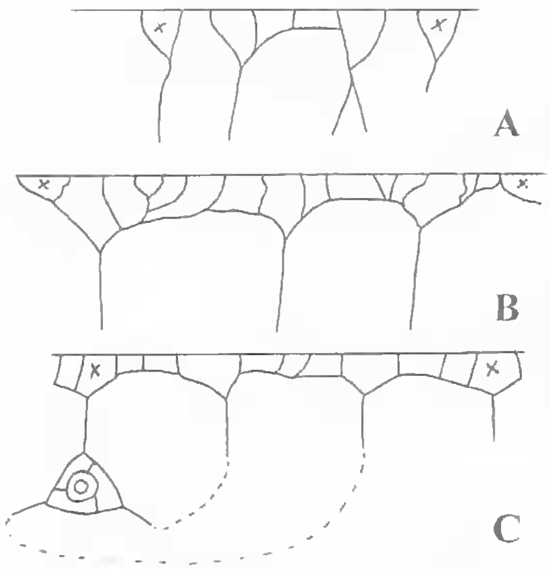


FIG. 24. *Playfordicrinus kellyensis* gen. et sp. nov. Schematic plating arrangement from camera lucida sketches; the 2 marks at either end of each sketch indicate the same plate and thus the full circumference of the cup. A, smallest (5mm long) cup NMVP100319 (Fig. 23F-J) showing 2 radials. B, largest (9mm long) NMVP100318 (Fig. 23A-E) showing all 3 large plates as inferradials. C, schematic with basals shown and indication of relation to inferradials QMF36203 (Fig. 22A-D).

question may modify Rozhnov's (1981) phylogeny but would not change the argument herein.

**Playfordicrinus kellyensis** sp. nov.
(Figs 21-24)

ETYMOLOGY. For Kelly Pass through which access is gained to the type locality.

MATERIAL. Holotype: NMVP100315. Paratypes: NMVP100311-100314, 100316-100321, QMF36203 all from NMVPL1938, S of the Teichert Hills.

DIAGNOSIS. As for genus.

DESCRIPTION. Cup small, up to 10mm in diameter and 9mm long, subspherical, with distal sides becoming straighter (rather than distally incurving) during growth, with fine widely spaced granular ornament; plates very thick, body cavity small. Basals 3, forming subtriangular circlet around large circular attachment facet; each basal slightly curved around stem facet, shaped like a tick (i.e. with a long arm beginning near one interradial suture, expanding into distal projection at next interradial suture and short extension beyond distal projection), with distal projection sometimes reaching as far as point where suture divides distally (thus producing a 4 way sutural junction). Of 3 large plates in cup 1 always inferradial, other 2 may be either radials or inferradials; arm-bearing plates variable in number with growth, 7-14. Smallest specimens (5mm diameter) with 2 large radials, a large inferradial, 2 small radials and 3 pararadials. In largest specimen 3 large plates inferradials, 2 small radials and 12 pararadials. Radial facets almost as wide as plate except for narrow distal projections laterally; each projection paired with another on adjoining plate. In weathered specimens there is a striate comb-like outer lip to facet. Stem circular in section. Arms unknown.

REMARKS. Increasing number of arm-bearing plates and changing thecal shape from subspherical to more straight-sided are trends with growth which may be equated with trends in other lineages in the family. Comparisons of this species within the family are detailed above in the generic remarks.

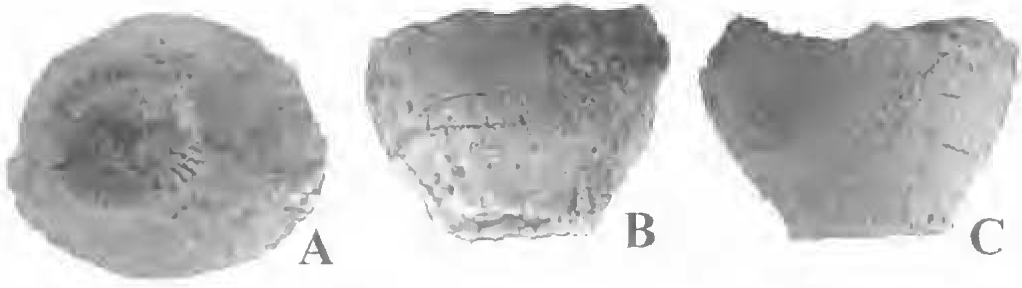


FIG. 25. Catillocrinid? indet., NMVP100322 from NMVPL1938, proximal (A) and two lateral (B,C) views, ×4.

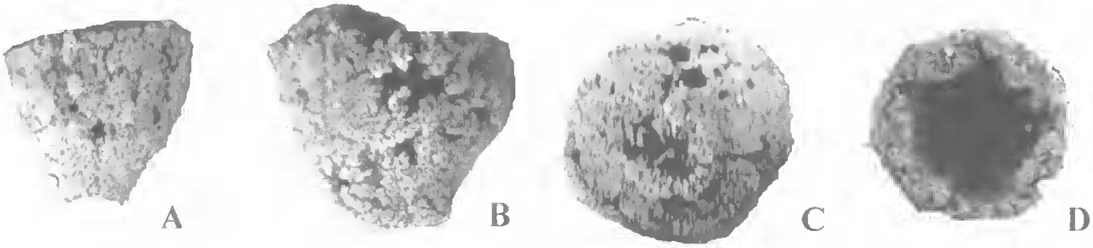

FIG. 26. *Stylocrinus tabulatus* (Goldfuss, 1839), all silicified cups from Frasnian part of Sadler Limestone SW of Wade Knolls, Paddy's Valley. A, C, lateral and proximal views of QMF40372, x3. B, D, lateral and distal views, respectively, of QMF36210, ×3.

Superfamily ALLAGECRINOIDEA Carpenter & Etheridge, 1881
Family CATILLOCRINIDAE Wachsmuth & Springer, 1886

**Catillocrinid**? indet.
(Fig. 25)

MATERIAL. NMVP100322 from NMVPL1936.

DESCRIPTION. Cup 4mm long, 4mm in diameter, conical. Basals 3, with 2 very large and one very small; stem facet large, with marginal crenularium and areola of similar width. Radial circlet unclear in parts, with at least 1 plate not reaching distal margin of cup, with 3 large radials and numerous small ancilliary ones. Distal surface of cup with small central cavity, with larger coarse multiple facets on larger radials and multiple narrow facets and fine intervening ridges on small radials.

REMARKS. This specimen is almost unidentifiable and its assignment to the Catillocrinidae is very tentative. No known catillocrinid has the plate arrangement interpreted in this specimen but the distal surface and the 2 large and 1 tiny basals suggest that family. As no other evidence is available this assignment is made very tentatively.

Superfamily BELEMNOCRINOIDEA S.A. Miller, 1883
Family SYNBATHOCRINIDAE S.A. Miller, 1889

**Stylocrinus** Sandberger & Sandberger, 1856

TYPE SPECIES. *Stylocrinus scaber* Sandberger & Sandberger, 1856 from the Middle Devonian of Germany by monotypy.

**Stylocrinus tabulatus** (Goldfuss, 1839)
(Fig. 26)

MATERIAL. QMF40372 and 36210 from insoluble residue of the Sadler Limestone taken by Alex Cook in 1998 from SE of Wade Knoll in the Paddy's Valley area.

DESCRIPTION. Cup 4mm long, 4mm diameter, low conical, with smooth thick plates. Basals 3, 2 large and 1 small; large ones supporting a radial symmetrically and sutured to 2 others distolaterally. Radials 5, pentagonal, with horizontal distal margin, in distal view thin at centre and thicker at interradial sutures; radial facet peneplenary, with distinct transverse ridge. Arms and stem unknown.

REMARKS. The genus had been restricted to the Middle Devonian of Europe (Schultze, 1867) and Russia (Dubatolova, 1971) but Strimple (1963) added *S. elimatus* from the Silurian Hunton Formation of Oklahoma. However, the distal view of Strimple's specimen shows the radial facet to be reclining on a thick central part of the radial plate (as thick as or thicker than the lateral part at the interradial sutures). This structure is much more reminiscent of *Phimocrinus* Schultze (1867, pl. 3, figs 6a, 7a) whereas the new Australian species with definite invagination at middle of each radial is identical with *Stylocrinus tabulatus* (Schultze, 1867, pl. 3, figs 4a, 5a). A number of subspecies have been identified in *S. tabulatus* (Dubatolova, 1971) but with length = width the Australian specimens appear intermediate between *altus* (length > width) and *depressus* (width > length). We thus assign them to the broader species concept.

When Teichert (1949) identified *Storthingocrinus* there is a distinct possibility that he had material of this species because the plating arrangement is identical; however, the radial facets of

*Storthingocrinus* are quite different and it has been suggested that it is a camerate crinoid (Prokop & Petr, 1997).

Subclass CLADIDA Moore & Laudon, 1943
Family CODIACRINIDAE Bather, 1890

**Codiacrinus** Schultze, 1867

TYPE SPECIES. *Codiacrinus granulatus* Schultze, 1867 from the Middle Devonian of Germany; by original designation.

REMARKS. This genus was discussed by Jell (in Jell & Holloway, 1983:16); it contains 7 species, *C. granulatus*, *C. schultzei* Follmann, 1887, *C. procerus* (Prokop, 1973), *C. ornatus* (Prokop, 1973) (probably a junior synonym of *C. granulatus*), *C. rarus* Jell in Jell & Holloway, 1983, *C. nicolli* sp. nov. and *C. secundus* Jell, 1999.

**Codiacrinus nicolli** sp. nov.
(Fig. 27)

ETYMOLOGY. For Robert Nicoll who collected some of the material.

MATERIAL. Holotype: WAM91.710 from QML1929. Paratypes: CPC34566-34577 from section 354 (9m level) on W side of McWhae Ridge (Nicoll & Playford, 1993). Other Material: QMF36204-36206 from QML1031, E side of Bugle Gap S of Wagon Pass.

DIAGNOSIS. Cup small, with granular ornament but no ray ridges; basals small, pentagonal, almost equidimensional, with proximal margin shorter than others; radials long, with angustary radial facets, with strong distal projections both sides of facet.

DESCRIPTION. Cup small, up to 11mm long and 8mm diameter, subglobose to subcylindrical, with broadly flared basal circlet, of very thick plates (body cavity less than 1/2 thecal diameter). Infrabasals 3 (in Fig. 22E there appear to be only 2, but it is a weathered base and the positions of the visible sutures suggest that the 3rd suture has been fused and thus the specimen aberrant), 2 large and equal and 1 small, separated by sutures in typical Y-shaped arrangement, with obtuse angle distally at base of sutures between basal plates, outflared away from stem. Basals pentagonal, with 4 equal sides and shorter proximal margin, up to 4mm across. Radials large, longer than wide, occupying most of theca; radial facet angustary, more than 1/2 radial width, subrectangular excavation into radials, with flat semicircular floor and convex butterfly-shaped inner surface, with lateral parts of radials of adjoining plates forming 5 projections distally. No anal plates in theca. Stem circular in section, very small diameter, with fine central lumen. Arms unknown.

REMARKS. Smaller size, type of radial facet, small infrabasal circlet, outflared infrabasal and basal circlets and stem diameter much less than that of cup distinguish this species within the genus. It is probably most similar to the type species particularly in comparison with Schultze's (1867, pl. 3, fig. 9C) second specimen which is more cylindrical than globose. It is quite distict from the other Australian species in the Pridoli and Lochkov of Victoria in its stem size, size of infrabasals, radial facets and ornament.

Subclass FLEXIBILIA Zittel, 1895
Order TAXOCRINIDA Springer, 1913
Superfamily TAXOCRINOIDEA Angelin, 1878
Family TAXOCRINIDAE Angelin, 1878

?**Taxocrinus** sp.
(Fig. 28D)

MATERIAL. QMF40360 from QML1031.

DESCRIPTION. Cup plates smooth. Infrabasals 3, azygous in C ray, visible externally, forming narrow margin to stem facet. Basals 5, pentagonal, equidimensional except posterior one; posterior basal much longer than others and also wider, hexagonal, with distal margin weathered and unclear but apparently with distal lateral corners curving towards axis of cup around a central semicircular part of margin that could be part of an aperture that may lead into an anal tube.

REMARKS. This basal cup fragment is too incomplete for species identification. The distal end of the posterior basal suggests the beginning of a tubular structure as in an anal tube suggesting the Taxocrinidae. Within that family, *Taxocrinus* Phillips in Morris, 1843, which ranges from the Middle Devonian to Lower Carboniferous of Europe and North America, has a symmetrical posterior basal leading directly into an anal tube and also has the stem facet restricted to the infrabasal circlet. However, it is retained in open nomenclature because it is so incomplete.

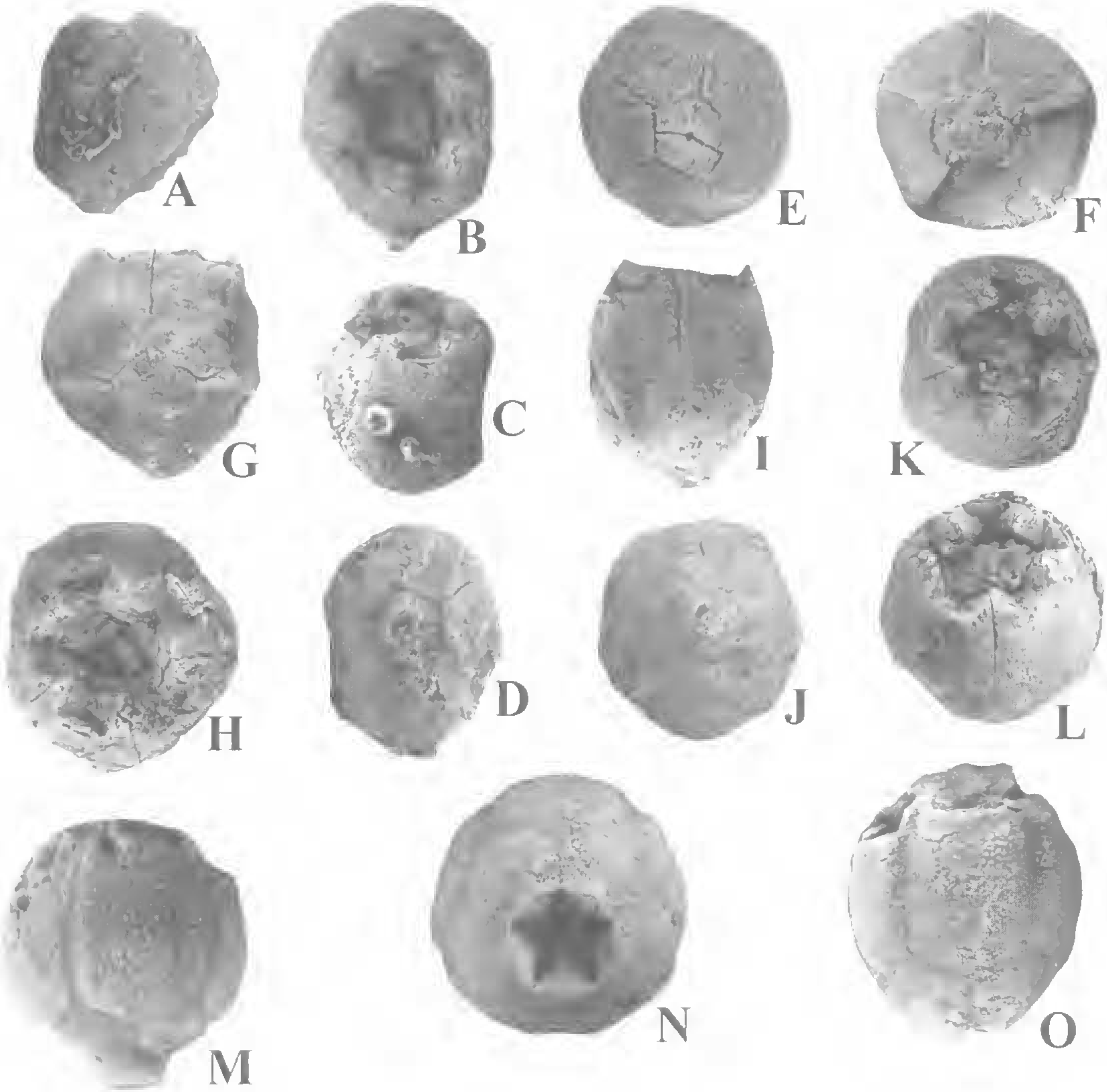


FIG. 27. *Codiacrinus nicolli* sp. nov. all from WCB354/9 (Nicoll & Playford, 1993) except M from QML1029 and N, O from QML1031. A-D, CPC34566, ×3. A, lateral view. B, distal view. C, oblique lateral view. D, proximal view. E, proximal view of CPC34567, ×3. F, distal view of broken theca showing thickness of shell, CPC34568, ×3. G, lateral view of CPC34569, x3. H, distal view of CPC34570, ×3. I,J, lateral and proximal views of CPC34571, ×3. K,L, distal and oblique views of CPC34572, ×3. M, lateral view of WAM91.710, ×7. N, O, proximal and lateral views of QMF36204, ×5.

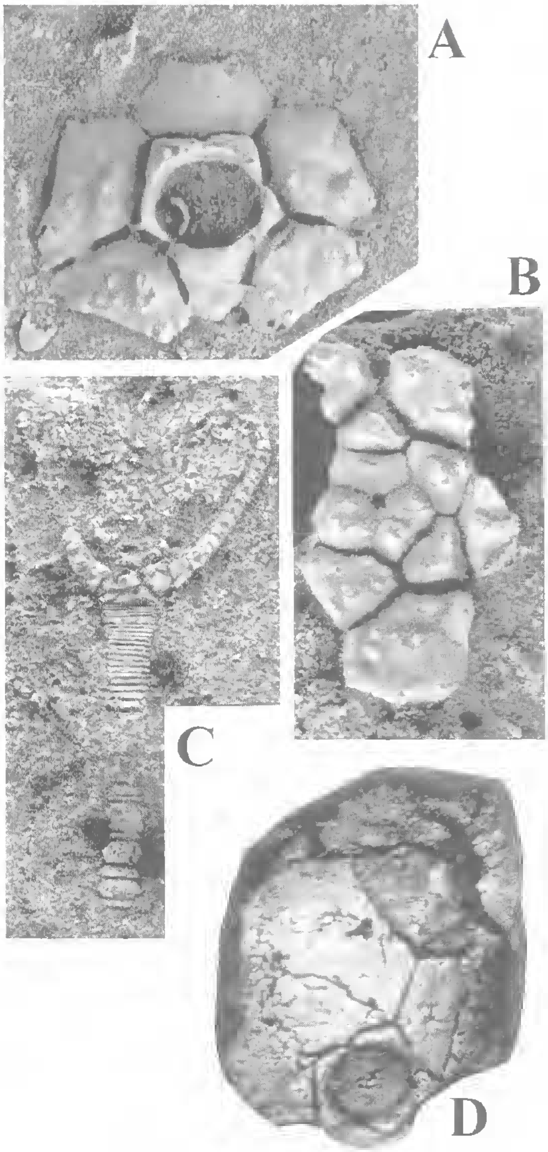


FIG. 28. A-C, *Forbesiocrinus* sp. A, proximal view of basal and radial circlets, NMVP100323 from NMVPL1930, ×4. B, internal view of base of cup showing infrabasal, basal and radial circlets, NMVP100324 from NMVPL1929, ×4. C, weathered section through whole animal showing differentiated stem and strongly incurved and coiled arms, QMF36207 from the Virgin Hills Formation W of Hull Range, ×2. D, ?*Taxocrinus* sp., basal view of cup fragment with infrabasal circlet visible around stem facet and large posterior basal at upper left QMF40359 from QML1031, ×4.

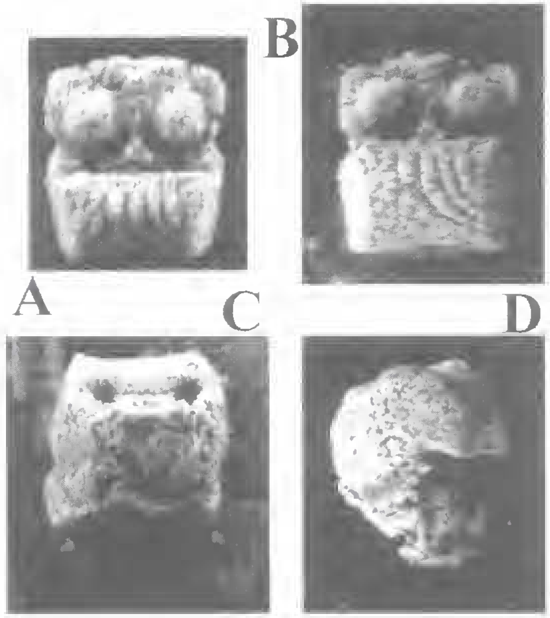


FIG. 29. Cyclocystoid indet., silicified marginal ossicle, QMF36209, ×3, from Frasnian part of Sadler Limestone SW of Wade Knolls, Paddy's Valley. A, B, ventral views of marginal ossicle tilted slightly differently to show the cupule zone and entries to radial ducts (A) and crest (B) more clearly. C, dorsal view showing entries to radial ducts. D, lateral view showing high rounded crest, cupule zone and circumferential canal.

Order SAGENOCRINIDA Springer, 1913
Superfamily SAGENOCRINOIDEA Roemer, 1854
Family SAGENOCRINITIDAE Roemer, 1854

**Forbesiocrinus** sp.
(Fig. 28A-C)

MATERIAL. NMVP100323 from NMVPL1930 and NMVP 100324 from NMVPL1929 and probably QMF36207 from the Virgin Hills Formation W of the Hull Range.

DESCRIPTION. Cup with flat base, plates with tuberculate ornament. Infrabasals 3, equal, pentagonal, concealed within stem facet. Basals 5, pentagonal, with only distal triangular tips visible laterally forming margin to stem facet; posterior basal with an extra side distally, supporting 2 anal plates, separating C and D radials. Radials 5, hexagonal, in contact with each other except in posterior interray; radial facet plenary. Stem tapering slightly distally, of extremly short columnals proximally, becoming heteromorphic (alternating long and short columnals with angular latus) distally.

REMARKS. Assignment to *Forbesiocrinus* is based on the posterior basal supporting 2 anal plates apparently symmetrically but the lack of arms prevents meaningful comparison with other species of the genus. The specimen in section from the Hull Range is doubtfully referred to this taxon but if correctly interpreted has the infrabasals completely concealed by the stem facet. In the other known flexible crinoid from the basin the infrabasals are evident laterally.

Class CYCLOCYSTOIDEA
Miller & Gurley, 1895
Family CYCLOCYSTOIDIDAE
S.A. Miller, 1882

**Cyclocystoid** indet.
(Fig. 29)

MATERIAL. QMF36209 from the Frasnian part of the Sadler Limestone SW of Wade Knolls in Paddy's Valley.

DESCRIPTION. Single marginal ossicle 1mm wide, 2mm in radial length and 1mm high, with bevelled lateral margins indicating that the marginal ossicles were not in contact throughout their lateral margins. Crest high, with almost circular lateral profile, with ornament of rounded (in section) ridges aligned in parallel curves across crest. Cupule zone with 2 circular cupules each with strong circular central tubercle, with sharp ridge between cupules, with narrow deep circumferential channel, with 2 relatively large radial ducts from centre of each cupule. Dorsal surface smooth.

REMARKS. The features of this ossicle are clearly in line with the Cyclocystoidea (Smith & Paul, 1982) but within the class it does not appear to fit any genus. The youngest described genus is *Sievertsia* last known from the Middle Devonian of Europe but that genus has flat or concave crests and dorsal surfaces and cannot accept the Australian ossicle. The ornament on the crest is unknown in any genus and this ossicle probably represents a new genus but it is retained in open nomenclature pending more complete material. Smith & Paul (1982: 677) reported an occurrence of the class in the Frasnian of Iowa, communicated to them by Terry Frest (pers. comm. 1980) but without illustration comparison is not possible. However, the occurrences in Iowa and Western Australia are the youngest known occurrences of the class and are valuable knowledge for that reason.

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## APPENDIX

### Localities Register

NMVPL1929. From more westerly of 2 stromatolitic limestone horizons mapped by Druce (1976, fig. 29) and Playford (1981, fig. 34) east of Millard Creek, 400-500m E of McWhae Ridge; collection made over 200m of strike 200-400m NNE of line of Section 4 of Druce (1976, fig. 29). Just NE of prominent westerly swing of creek this bed makes low ridge just above creek bank then after crossing creek outcrop area widens as its surface is exposed on low rising ground. GR4160 - 926262.
Age: Although Druce (1976, fig. 29) mapped only 2 stromatolite horizons in his section 4 he mentioned 3 such beds in his text (Druce, 1976: 11). His first stromatolite bed is presumably west of Millard Creek and not mapped; his second stromatolite bed is the first stromatolite bed of Playford (1981: 42) based on the assigned ages 'upper *Palmatolepis triangularis*' zone (Druce, 1976: 11) and 'immediately above the Frasnian-Famenian boundary' (Playford, 1981: 42).
Fauna: *Jaekelicrinus murrayi*, *Forbesiocrinus* sp.

NMVPL1930. From more easterly (i.e. younger) of two stromatolitic limestone horizons mentioned in siting NMVPL1929 and collecting from along a similar strike distance (200m) due E of that mentioned above for NMVPL1929. This horizon forms prominent line of ridges with E dip slope of 10-20 and W scarp over which Casey Falls pour. GR4160 - 926262.
Age: *Palmatolepis quadrantinodosa* Conodont Zone of Druce, (1976: 11) or lower *marginifera* Conodont Biozone (Becker & House, 1997, fig. 9).
Fauna: *Jaekelicrinus murrayi*, *Forbesiocrinus* sp.

NMVPL1931 (= UQL3395 = GSWA21939 = QML1030). From red muddy carbonates of Virgin Hills Formation on left bank of creek above Casey Falls extending from near top of ridge of second stromatolite horizon E to sharp southerly bend in creek; collections from 30-40m of section almost immediately above stromatolite horizon. GR4160 - 926258. GPS location 18

Age: *Palmatolepis quadrantinodosa* Conodont Zone of Druce (1976: 12). Petersen (1975) assigned an age of do II within the *Cheiloceras* zone. This horizon equates to the 'sponge garden facies' of Becker & House (1997: 140, figs 7, 8) which they place in the *Pernoceras delepenei* Goniatite Biozone in the upper *marginifera* Conodont Biozone.
Fauna: *Wacrinus caseyensis*, *Wacrinus millardensis*.

NMVPL1938 (=K190). On GSWA track from Kelly's Pass to Teichert Hills 200-300m N of 90 turn from E to N

just NE of small prominent outlier of Permian Grant Formation (Playford, 1981, fig. 29; Playford & Lowry, 1966, plate 4); low lime knoll with some stromatolites. GR4160 - 933300.
Age: Petersen (1975:53) assigned a probable age of do II and this equates to the late *crepida* or early *rhomboidea* Conodont Biozones which accords with the co-occurring goniatites.
Fauna: *Playfordicrinus kellyensis*.

NMVPL1936 (=K177). At first bend in creek downstream from spring due S of Teichert Hills (Playford & Lowry, 1966, plate 4). Rubbly outcrop above stromatolitic horizon. GR4160 - 942301.
Age: *Palmatolepis rhomboidea* Conodont Biozone (do II) (Glenister & Klapper, 1966: 838).
Fauna: *Jaekelicrinus murrayi*, *Playfordicrinus kellyensis*, holdfasts, Catillocrinid indet.

NMVPL1939. 200-300m SSW of Millard Creek at S end (slightly W) of McWhae Ridge on ridge on left bank of minor left bank tributary marked by Druce (1976, fig. 29); 20m below base of Bugle Gap Limestone. GR4160 - 920256.
Age: At level of *Maenoceras* Lsts (Becker & House, 1997, fig. 7) assigned to the lower *marginifera* Conodont Biozone.
Fauna: *Wacrinus millardensis*, *Jaekelicrinus murrayi*.

QML1031 (=NMVPL1940, = BC23-3 of Seddon (1970), = T66 of Teichert (1949), = site of section 12 of Druce (1976)). On top of most southerly of 5 low hills stretching in a line (for about 1.5 km) SSW from Waggon Pass in Bugle Gap. GR4160 - 905355, GPS location 18

Age: Michael House (pers. comm.) assigns this locality to the *Crickites lindneri* Goniatite Biozone (Becker & House, 1997, fig. 8) which equates to the *linguiformis* Conodont Biozone.
Fauna: *Hexacrinites brownlawi*, *Codiacrinus nicolli*, *Hyperoblastus buglensis*, *Jaekelicrinus murrayi* and *Taxocrinus* sp.

NMVPL1942 (= BC44-1 of Seddon (1970, p. 746)). From section at N end of Ngumban Cliff (Playford, 1981, fig. 29) (i.e. E wall of S entrance to Bugle Gap, just N of Pinnacle Spring). Collection from some 40-50 m of section above lower stromatolite horizon. GR4160 - 891241.
Age: Druce (1976, p. 16), in his Section 25, which is probably a parallel section, dated the lower stromatolite horizon in the *Palmatolepis crepida* Conodont Biozone (do II) and the second stromatolite horizon in the basal *P. quadrantinodosa* Biozone (do II). Very likely the *rhomboidea* Conodont Biozone.
Fauna: *Wacrinus millardensis*, crinoid stems in stromatolites.

NMVPL1950-1956 (=T16 = WAPET H = K495). Section between Margaret River and NeedleEye Rocks on first left bank tributary of first left bank creek from Margaret River N of Mount Pierre (Mount Pierre Creek); well exposed silty carbonates with cleaner limestone beds standing up above general outcrop near base. GR4061 - 042783 to 024776.
0-110m no fossils
18 A (= 1950) - 110-147m
18 B (= 1951) - 147-155m *Jaekelicrinus murrayi*, holdfasts.
18 C (= 1952) - 195-210m *Jaekelicrinus murrayi*, holdfasts.
18 D (= 1953) - 210-232m
18 E (= 1954) - 372m
31 F (= 1955) - 382m
31 G (= 1956) = last 10m of section beneath first prominent grey limestone bench on NE side of Needle Eye Rocks; in head of gully opening to SE.
Age: Most of the WAPET H section belongs to the *Pseudoclymenia australis* Ammonoid Biozone (Thomas Becker pers. comm. 1997) which equates to the lower *trachytera* Conodont Biozone (Becker & House, 1997, fig. 8).

QML1029. In bank of Millard Creek slightly N of W from Casey Falls, on the line of section B-C on figure 33 of Playford (1981;35). GPS location 18 44.07'S, 126 05.18'E.
Age: Very late Frasnian, late *Pelmatolepis linguiformis* Conodont Biozone equivalent to the *Crickites lindneri* Ammonoid Biozone (Becker & House, 1997, fig. 9).
Fauna: *Melocrinites solidus* sp. nov., *Codiacrinus nicolli* sp. nov.